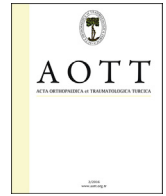


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Return to sport activity after anterior cruciate ligament reconstruction in skeletally immature athletes with manual drilling original all inside reconstruction at 8 years follow-up

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ABSTRACT

Objective: Anterior cruciate ligament (ACL) tears are common injuries in adolescent athletes, especially in those who bear high stress on their knees due to shearing forces. The goal of the surgical procedures in skeletally immature patients is to restore joint stability avoiding the adverse effects on the growth process.

The aim of this study was to verify the return of the skeletally immature professional athletes to sports in the long-term, following ACL reconstruction with the original all-inside technique and with manual drilling.

Methods: This study included 24 athletes (14 boys, 10 girls; mean age: 13.15 years, range: 9–14 years) who had radiographic evidence of open physes, were less than 14 years of age at the time of surgery and those with a minimum follow-up of eight years. All patients completed a questionnaire, the IKDC subjective knee evaluation form, and Tegner Activity Scale. Biomechanical outcomes of the KT-1000 arthrometer, gait analysis, and stabilometric and isokinetic results were also evaluated. A plain radiograph of both lower limbs was taken to obtain a precise measurement of the limb length and mechanical axis angles.

Results: The patients returned to sport activities in a mean time of 6.43 months. No rerupture or resurgery due to growth abnormalities was observed. The mean difference in length between the operated and contralateral legs was 0.4 (range: –0.2 to 0.7) cm. The mean side-to-side difference measured with the KT-1000 arthrometer was 5.2 (range: 3.5 to 7) mm in the preoperative and 0.8 (range: 0 to 2.5) mm in the postoperative measurements.

Conclusion: In conclusion, the original all-inside technique with manual drilling with a half tunnel and short graft seems to be a very effective technique for the surgical management of ACL injuries in pediatric/adolescent athletes. A good rate of return to sports at pre-injury levels or higher, high patient satisfaction and a decent motor and proprioceptive function is possible as shown by our analysis.

Level of evidence: Level IV, Therapeutic study.

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Anterior cruciate ligament (ACL) tears are common injuries in adolescent athletes, especially in those who bear high stress on their knees due to shearing forces.^{1–3} The goal of the surgical procedures in skeletally immature patients is to restore

joint stability avoiding the adverse effects on the growth process.⁴

In order to avoid the risks that may occur with an unstable knee, some authors believe that a change in the young athletes' activity program before starting the standard program could get them ready for skeletal maturity. However, it is clear that prohibiting a young athlete from doing sports is not a feasible solution. Restoring the joint stability is necessary to prevent secondary meniscal and

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cartilaginous lesions, and allow young athletes to continue with their careers.^{5–7}

Clinical studies have shown good functional outcomes and high rates of return to sports after ACL reconstruction among young patients, through different technical possibilities to create bone tunnels^{8–11}; the transphyseal technique,⁶ the mixed technique,¹² the extraepiphyseal technique¹³ and physeal sparing.¹⁴ Most of the authors make their decisions based on the presence or absence of the patient's residual growth plate.⁴

Mechanical and biological reasons may affect the bone growth. The mechanical reasons might arise from the mechanism of fixation and the size of the bone graft. The passage of the graft in the growth plate or positioning of a fixation medium in the metaphysis can cause an arrest of the normal growth. The biological reasons are represented by possible complications of graft integration, and above all, by the thermal shock of mechanical drilling on the bone, which could cause heat necrosis and subsequently lead to epiphyseal fusion.^{15,16}

The aim of this study was to verify the return of the skeletally immature professional athletes to sports in the long-term, following ACL reconstruction with the original all-inside technique and with manual drilling.

Patients and methods

The design of our study is a single surgeon (GC), single technique, and retrospective series of ACL reconstruction employing the 'original all-inside technique'^{17,18} on preadolescent patients with knee anterolateral rotatory instability after sustaining total tear of the ACL.

All reconstructions were performed by the senior author between the years 2002 and 2006. The Institutional Review Board approved the study.

Twenty-nine patients who had radiographic evidence of open physes, were less than 14 years of age at the time of surgery and those with a minimum follow-up period of eight years were included in the study. Twenty-four of them (14 boys, 10 girls; mean age: 13.15 years, range: 9–14 years) agreed to participate in the clinical interviews, examinations, and biomechanical and radiographic evaluations.

According to the Tanner scale, one patient was Tanner 1, three were Tanner 2, five were Tanner 3, twelve were Tanner 4 and one was Tanner 5 at the time of surgery. All patients sustained acute injuries and had no significant difference in limb length (<0.5 cm). Long-cassette radiographs were obtained preoperatively to measure the limb length, mechanical axis and the physeal length.

Fifteen of the patients were athletes in youth teams; 14 of them were footballers, four were volleyball players, three were basketball players, one was a cyclist, one was an artistic dancer, and one was a fighter.

Twelve patients had accompanying meniscal tears; six of them had longitudinal lesions of the medial meniscus, three had longitudinal lesions of the lateral meniscus and one had a bucket handle lesion of the medial meniscus. All these patients were surgically treated at the same time of the ACL reconstruction; two with selective meniscectomy and 10 with meniscal sutures using the Mulberry technique (three sutures failed and meniscectomy was performed as a revision surgery).

The original all-inside ACL reconstruction was performed under peripheral or general anesthesia and with the use of a tourniquet. Employing a lateral infrapatellar access and a standard anteromedial access, the chondral and meniscal lesions were treated when indicated. The notch was debrided and the remnants of the ACL were left when possible. 2.0-mm guide wires were introduced transphyseally into the femur and tibia with the out-in/free-hand

techniques and two small tunnels with a diameter of 4 mm were drilled both into the tibia and the femur (Fig. 1a and b).

Quadrupled gracilis tendon grafts were used for all ACL reconstructions. The grafts were harvested and measured in size, and the tibial and femoral half tunnels were manually drilled in-out in respect with the graft measurements (Fig. 2a and b). Then, the grafts were tensioned and fixed; femoral fixations were performed using the ENDOBUTTON polyester sutures and tibial fixations were carried out using small, resorbable interference screws from the outside.

Patients were immobilized in extension brace for 10 days after surgery. No weight-bearing was allowed for 21 days. Then, partial bearing was encouraged with two crutches for five days and with one crutch for four days. Full weight-bearing was allowed after 30 days. Isometric exercises were started as soon as possible and knee flexion was started on the 10th postoperative day. Playing sports was allowed only after biomechanical examinations confirmed a good muscular and articular functional recovery in isokinetic and kinematic tests. If the menisci were sutured, weight-bearing was forbidden for one month.

All recalled patients completed a questionnaire. The patients were facilitated by two blind examiners (MP and MB) who asked them to report their clinical and sportive histories. All patients completed a questionnaire, the IKDC subjective knee evaluation form and Tegner Activity Scale. One blinded biomechanics technician performed the biomechanical evaluations and one blinded examiner analyzed the biomechanical outcomes of the KT-1000

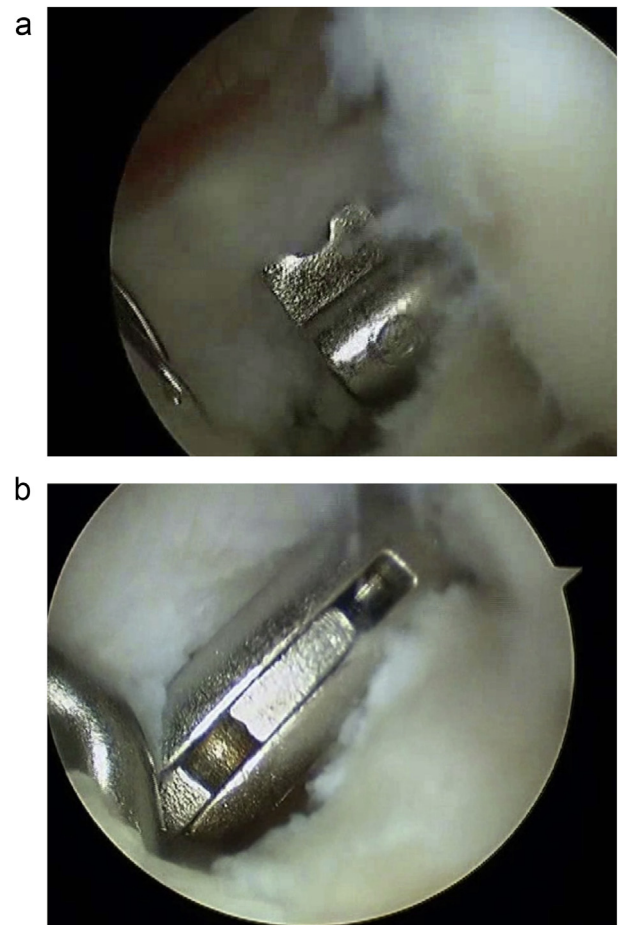


Fig. 1. (a, b) Introduction of guide wires into the femur and tibia with the out-in/free-hand techniques and drilling of the tunnels.

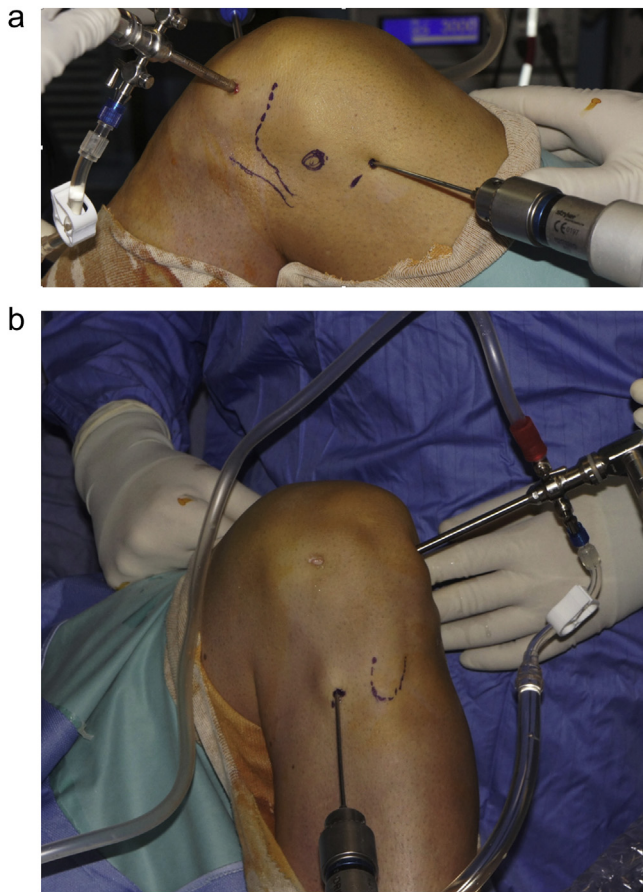


Fig. 2. (a) Femoral and (b) tibial landmarks for manual in-out drilling.

arthrometer, gait analysis, and stabilometric evaluation with Bertec platform and isokinetic muscular measurement of the thigh flexors and extensors using a Biodex device. A plain radiograph of both lower limbs, with the pelvis included, was taken to obtain a precise measurement of the limb length and the mechanical axis angles (hip-knee-ankle).

Descriptive statistics were used to summarize the outcome variables.

Results

All patients returned to playing sports after a mean period of 6.43 months (range: 4 months and 25 days to 7 months and 23 days). Nine patients who were not a member of a youth team either returned to playing sports at a lower sportive level or changed their field of sports activity due to reasons not directly related to their knees. At the final follow-up, the mean Tegner activity score, which was 9.2 before the injuries, decreased to 8.7.

No rerupture has been reported in our series. Ten patients (6 girls, 4 boys) sustained a contralateral ACL rupture after a mean period of 32 (range: 10 to 85) months and underwent subsequently a contralateral surgical ACL reconstruction. Six of them underwent an additional surgery; one patient for removal of the symptomatic hardware and five for meniscectomy (three of these patients were treated with meniscal sutures).

No resurgery due to growth abnormalities was required. The mean difference in length between the operated and contralateral legs was 0.4 (range: -0.2 to 0.7) cm. None of the patients reported problems related to discrepancies in limb length. No difference was

detected in the mechanical axis angles between the operated and contralateral legs.

The mean side-to-side difference measured with the KT-1000 arthrometer was 5.2 (range: 3.5 to 7) mm in the preoperative and 0.8 (range: 0 to 2.5) mm in the postoperative measurements. We also calculated the side-to-side mean difference of the 14 patients that did not undergo a contralateral ACL surgery; the mean difference was 5.4 (range: 3.5 to 7) mm preoperatively and 1.5 (range: 0 to 2.5) mm postoperatively.

Stabilometric analysis showed a good proprioceptive control in all our patients. The mean difference in the average speed of center of gravity oscillation was 2.13 mm/s and the side-to-side mean difference of the 95% confidence ellipse area was 20.53 (range: 15.73 to 88.73) mm².

Isokinetic evaluation of muscular function showed a slight reduction in flexion and extension strength of the operated legs in comparison to the contralateral ones. The side-to-side mean difference measurements showed an 11% (range: 1%–21%) reduction in the flexion strength and 6% (range: 4%–23%) reduction in the extension strength, with a good ratio between the extensor and flexor muscles strength (mean ratio: 65.25%, range: 53%–78%). We consider a ratio between 40% and 80% as normal.

During clinical evaluation, the mean difference in the calf circumference of the operated and non-operated legs was 1.6 (range: 0 to 4) cm. None of the patients had a positive Jerk, anterior drawer, or Lachman test. Two patients who underwent a medial meniscectomy had a positive Apley test for the medial meniscus.

At the final follow-up, the Lysholm score was 100 and the mean IKDC score was 98.58 (range: 95.4 to 100).

Discussion

As described in the literature, we did not find any pathological values in our series. The original all-inside technique implies the use of a manual drill; just one tendon (in most cases utilizing the gracilis tendon is enough to obtain good results) and smaller bone tunnels in comparison to the classic technique, which means a lower possibility of thermal injury than the mechanical drilling and greater preservation of the bone stock and tendon resources in pediatric/adolescent athletes.

Numerous studies highlighted the growth abnormalities after ACL reconstruction; most often describing the operated limb as shortened in comparison to the non-operated one.^{19–21} Furthermore, a meta-analysis of over 900 cases⁸ described growth abnormalities in 2.1% of the cases. Despite not distinguishing the different reconstruction techniques, the authors demonstrated how the use of hamstring tendons for ACL reconstruction in skeletally immature patients had less risk to cause leg length and leg axis discrepancies in comparison to other surgical techniques.

It has also been described that ACL reconstruction in very young patients can cause stimulation of the growth plate, thus resulting in hyper-elongation of the operated leg.^{2,22} Abnormal axis deviations (mainly in valgus and genu recurvatum) were reported in the literature with lesser incidence with the majority of them being tibial axis deviations.^{23,24} No significant change in the axis or length was observed in our study.

The original all-inside original method, using the out-in/free-hand technique, allows for a 4.5 mm femoral tunnel with completely independent direction from the tibial tunnel, which means being close to the isometric position and avoiding damage to the growth plate.¹⁸ In addition, the risk of bone growth arrest is greater when heat is produced in proximity to the lateral side of the distal femur epiphyseal plate, but manual retrograde drilling avoids epiphyseal plate damage by averting the production of heat.^{25,26}

In our series, individuals who were at professional clubs had a higher return to sports than those who were not. This can be explained by different aspirations of the athletes and more accurate and precise application of the rehabilitative program.

A very important 'trick' to avoid damage to the physis during the original all-inside reconstruction is to perform accurate drilling of bone tunnels with complete circles hand movements and use short grafts and short tunnels; tunnels should not remain empty and grafts should be press-fit within the bone tunnels. No pre-stressed grafts is needed as excessive graft tension can cause growth disorder.²⁷

Patients playing in youth teams have all become pro-athletes, thanks to high personal aspirations and good surgical outcomes. A little number of patients changed their field of sports activity due to reasons not related to the reconstruction outcomes but due to other factors including changes in lifestyle and growing old.

The biggest limitation of our study was the absence of a control group.

Today, there is still a lack of evidence about how to deal with adolescent athletes with an ACL tear. Surely, data from the literature and our study is encouraging the performance of the surgery immediately after the tear. In conclusion, the original all-inside technique with manual drilling with a half tunnel and short graft seems to be a very effective technique for the surgical management of ACL injuries in pediatric/adolescent athletes. A good rate of return to sports at pre-injury levels or higher, high patient satisfaction and a decent motor and proprioceptive function is possible as shown by our analysis. However, studies with a control group are necessary to define more definitive guidelines.

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