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ORIGINAL ARTICLE • KNEE - ARTHROSCOPY

The biological respect of the posterolateral bundle in ACL partial injuries. Retrospective analysis of 2 different surgical management of ACL partial tear in a population of high-demanding sport patients

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Abstract

Introduction Most of the techniques described in the literature for the repair of chronic partial ACL tears do not spare the intact portion of the ligament. Aim of this study was to perform a retrospective analysis of the results obtained from the same ACL reconstructive surgical technique applicated by sparing or not AM bundle in a population of 42 sports patients.

Materials and methods From 2010 to 2012, 42 patients who suffered ACL partial tear injury with rupture of posterolateral bundle were randomly divided in two groups homogenous for sex, age and sport-level activities. The first group with 22 patients performed ACL reconstruction with ST-GR over-the-top technique sacrificing the anteromedial (Removing AMT Group) remaining bundle intact; otherwise, the second group with 20 patients performed the same ACL reconstruction using only ST and maintaining AM bundle (Sparing AMT Group). All the patients were followed up by MRI evaluation at 12 months and clinical evaluation with IKDC score, Tegner score at 6, 12, 24, 36, 48 and 60 months. KT-1000 instrument was performed at 12 months. The results were analyzed statistically to evaluate differences between the two groups in terms of subjective outcome, and stability and for all the tests $P<0.05$ was considered significant.

Results We did not observe any failure at final follow-up. IKDC subjective score at final follow-up in Removing AMT Group was 91.2 ± 2.3 in Sparing AMT Group was 92.4 ± 2.7. Tegner score at final follow-up was 7.2 ± 2.1 for Removing AMT Group and 7.8 ± 1.8 for Sparing AMT Group. Arthrometric evaluation performed with KT-1000 at final follow-up showed a side-to-side difference of 0.9 ± 1.3 mm in the Removing AMT Group against 0.8 ± 1.0 mm in the Sparing AMT Group. Return time to the sport was 7.1 months for Removing AMT Group otherwise 6.1 months for the Sparing AMT Group.

Conclusions Both the described techniques in this study demonstrated to be able to guarantee a successful outcome. However, although no statistically significant differences were evident in terms of subjective and objective outcome between these techniques some evident benefits were evident using the sparing bundle technique in Sparing AMT Group such as better clinical scores at the final follow-up and an earlier return to sport activity.

Keywords Knee · ACL · Sport injury

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Introduction

Anterior cruciate ligament (ACL) rupture is a common injury, especially in athletes, with an annual incidence in the USA of about 200,000, and at least 100,000 patients receiving arthroscopic reconstruction [15, 25, 38]. Although ACL injuries are more frequently complete, partial injuries have also been described, and they frequently involve a non-contact pivoting injury, typically a change in direction or sudden deceleration. Albeit these lesions are partial, patients are not able to perform their sport activity as usual due to a sensation of instability [21, 26, 27, 31, 41]. The ACL is composed of two bundles, anteromedial (AM) and posterolateral

(PL); each of these bundles has a distinct function in order to ensure knee stability: the AM bundle is tight in flexion, locking knee anteroposterior translation, while the PL bundle is tight in extension, locking knee rotation [3]. When a partial lesion involves the AM bundle, the knee suffers of an excessive anteroposterior laxity with frequently positive Lachman test and negative Pivot shift test; on the other hand, when the PL bundle is injured, the knee suffers from abnormal rotational instability with trace of positive Pivot shift test and positive Lachman test [3, 10, 14]. MRI seems to be the most accurate imaging evaluation to detect ACL partial tear, but the diagnostic certainty of a single-bundle ACL is only given by an arthroscopic procedure [10, 12, 30]. In the last decade, the principles of modern ACL reconstruction are more and more oriented toward an anatomical reconstruction retaining the ACL remnant as much as possible, like it happens in the so-called ACL-augmentation reconstruction techniques. Although these anatomical principles are an excellent starting point, these techniques have encountered several critical issues over the years. These include understanding the validity of the intact bundle, complexity in checking arthroscopically the real lesion of one of the two bundles and, finally, the poor field of vision that can lead to errors when performing tunnels or when verifying menisci's integrity.

The aim of this study was to evaluate, in a retrospective analysis (Case–Control observational analytic Study according to Oxford CEBM guidelines), results obtained from the same ACL reconstructive surgical technique performed by sparing or not sparing the AM bundle (with proven PL bundle lesion) in a population of 42 athletes.

Materials and methods

Between October 2010 and November 2012, a consecutive series of 42 patients with mean age of 24.2 ± 5.4 years (17.5–31.7) who suffered ACL partial tear injury with rupture of posterolateral (PL) bundle diagnosed with MRI, were included in this study. Inclusion criteria were patients with partial ACL tears according to the clinical and arthroscopic criteria described by Barrack et al. [6]: Lachman's test scores of 0 or 1 + (less than 5 mm); negative or only trace positive Pivot shift test; and a significant portion of at least one healthy and potentially functional bundle as judged by palpation with a probe and arthroscopic anterior drawer testing, MRI aspect compatible with partial tear and associated lesions included meniscal injuries. Exclusion criteria were chondral lesions, posterior cruciate ligament (PCL) lesion, medial collateral ligament (MCL) lesion, lateral collateral ligament (LCL) lesion, unstable contralateral knee, systemic or local infection and lower limb malalignment requiring surgery. All patients were followed up by MRI evaluation at 12 months and clinical evaluation at 6, 12, 24, 36, 48 and 60 months. KT-1000 instrument was performed at 12 months.

These 42 patients were randomly divided into two groups: highly homogeneous for associated lesions, age, sex, time from injury to surgery and level of sport activities performed (Fig. 1). Lesions of the posterior horn of the medial meniscus existed in 15 patients (7 patients in Removing AMT Group ad 8 patients in Sparing AMT Group), and lesions of the posterior horn of the lateral

Fig. 1 Demographics and preoperative findings

	SPARING AMT		REMOVING AMT	
NUMBER OF PATIENTS	20		22	
MALE	11		14	
FEMALE	9		8	
MEAN AGE	24,2 ± 4,1 years		24,3 ± 3,4 years	
DOMINANT LEG INJURY	13		15	
MENISCUS INJURY LESIONS	12 (TOTAL LESIONS)		11 (TOTAL LESIONS)	
	MEDIAL	LATERAL	MEDIAL	LATERAL
	8	4	7	4
CHONDRAL LESIONS (I or II ICRS GRADE)	3		4	
TIME FROM INJURY TO SURGERY	4,3 months		5,2 months	
IKDC OBJECTIVE PRE-OP	A	0 patients	A	0 patients
	B	0 patients	B	0 patients
	C	3 patients	C	3 patients
	D	17 patients	D	19 patients
TEGNER PRE-OP	1,8		1,8	

meniscus existed in 8 patients (4 patients in Removing AMT Group, 4 patients in Sparing AMT Group) (Fig. 1). The first 22 patients (Removing AMT Group) underwent ACL reconstruction with ST-GR over-the-top technique removing the anteromedial (Removing AMT). Among these, 12 patients were soccer players, 4 patients were basketball players, 2 patients were volley players, 2 patients were rugby players, and 2 patients practiced martial arts. In the second group, 20 patients underwent the same ACL reconstruction using only ST sparing intact AM (Sparing AMT) bundle. Among these, 14 patients were soccer players, 2 patients were basketball players, 2 patients were volley players, 1 patient was a rugby player, and the last 2 patients practiced martial arts (Fig. 2). Clinical evaluations with IKDC and Tegner scores were conducted on all patients preoperatively and 6, 12, 24, 36, 48 and 60 months (M) postoperatively; no patient was lost at final follow-up (FU) (Fig. 1). All patients underwent a radiographic evaluation consisting of anteroposterior (AP), lateral views and MRI preoperatively. Arthrometric assessment was achieved postoperatively and at each follow-up for up to 60 months postoperatively with the KT-1000 arthrometer (MEDmetric Corporation, San Diego, California) by means of the manual maximum displacement test. After 12 months, control MRI was performed in all subjects. The same rehabilitation protocol was applied to both groups: the first 4–6 week after surgery the main purpose was to control pain and swelling and protect graft healing. Furthermore, every patient was stimulated to achieve 100°–120° of knee flexion obtaining a full passive and active extension of the knee symmetric to the contralateral knee, and then progression to full weight bearing, reaching normal gait. After this preliminary phase, at 6 weeks after surgery the rehabilitation protocol focused on strength recovery, balance activity and neuromuscular control teaching closed and open kinetic chain exercises in order to prepare patients to their return to sport activity. Three months after surgery every residual flexibility or strength deficits must be completely recovered, and patient should be able to run for at least half an hour without problems before accessed to the final stage. This phase consisted of completing the entire functional rehabilitation spectrum in order to gain the pre-injury level of sport participation: when patients achieved approximately a quadriceps index of 85% or greater, they could start plyometric activities, cutting, pivoting and sprinting. Once the level of tolerance to these exercises was enough, patients could be considered for returning to sport by adding some sport-specific exercises to rehabilitation, leading to the final step: return to the court. Statistical analysis was performed with SPSS version 15.0 software (SPSS Inc, Chicago, Illinois, USA). For all tests, a P value below 0.05 was considered significant.

Surgical technique

A preliminary arthroscopic evaluation was performed by anterolateral and anteromedial portals, with patients under general or peripheral anesthesia, with the use of a tourniquet. The entire length of the ACL was examined to assess the extent and type of damage. Palpation of the residual ligament enabled mechanical strength to be assessed, and the anterior drawer maneuver performed under arthroscopic

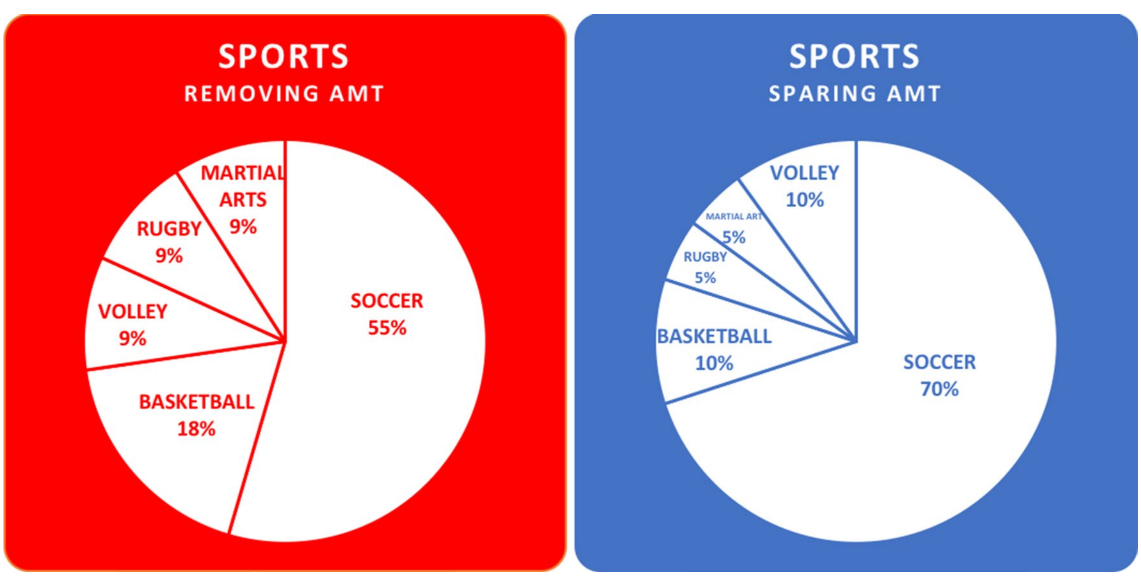

Fig. 2 Sport distribution

control provided a functional evaluation; the knee was then tested in "figure of 4" (Cabot) position for better assessment of the remnants of the PL band [35]. During the arthroscopic examination, partial meniscectomies were performed when required. A vertical incision in the proximal medial metaphysis of the tibia was made to isolate the pes anserinus. Patients who underwent Removing AMT underwent an over-the-top ACL reconstruction harvesting both the semitendinosus and the gracilis, sparing their tibial insertion. After removing any residual muscle tissue, the proximal third of the 2 tendons was tacked with 4 non-reabsorbable suture threads (No. 2 Ethibond; Ethicon, Somerville, New Jersey). A tibial tunnel was created with a guidewire starting 5 mm medially and 5 mm superiorly to the bone insertion of the gracilis tendon. The emergence of the tibial guidewire was guided by the residual of the torn ACL. The intra-articular emergence was placed at the center of the native footprint. The tibial tunnel was drilled using a cannulated reamer. The diameter of the tunnel depended on the size of the graft. An 8-mm reamer was used to perform tibial tunnel. A messenger wire was passed into the joint through the tibial tunnel and taken through the anteromedial portal. The lateral femoral condyle (LFC) was then exposed through a lateral incision. A second messenger wire was passed in the OTT position through the superolateral portion of the intercondylar groove and taken outside the tibial tunnel using the previous messenger wire. The graft was passed in the OTT position. Before graft fixation, no cyclic loading was performed. The graft was manually tensioned by an assistant and fixed with 1 or 2 titanium staples with the knee in 90° flexion, a posterior drawer maneuver applied to the anterior tibial shaft and the foot placed in external rotation. For patients in Sparing AMT Group, only the semitendinosus was harvested maintaining its tibial native insertion. The tibial tunnel was performed similarly to Removing AMT Group, but the emergence was located just anteriorly to the posterior margin of the ACL footprint. As previously described, the graft was passed through the tibial tunnel in OTT position, paying attention that its intra-articular course was in line with the remaining AM bundle, and then fixed to LFC. The tendon's tail was taken backwards anchored to a thread and fixed by tenodesis on the anatomical insertion of the hamstring tendons (Fig. 3).

Results

No postoperative complications were observed. No additional traumatic events were reported in any patient up to 5 years postoperatively. IKDC and Tegner clinical scores showed a progressive increase from pre-surgery level in both techniques, and this was confirmed at the last follow-up (Figs. 4, 5). In particular, mean IKDC subjective score at final follow-up was 91.2 ± 2.3 in Removing AMT Group and 92.4 ± 2.7 in Sparing AMT Group. Analyzing the collected data, the best IKDC result occurred at 48 months (90.1) for

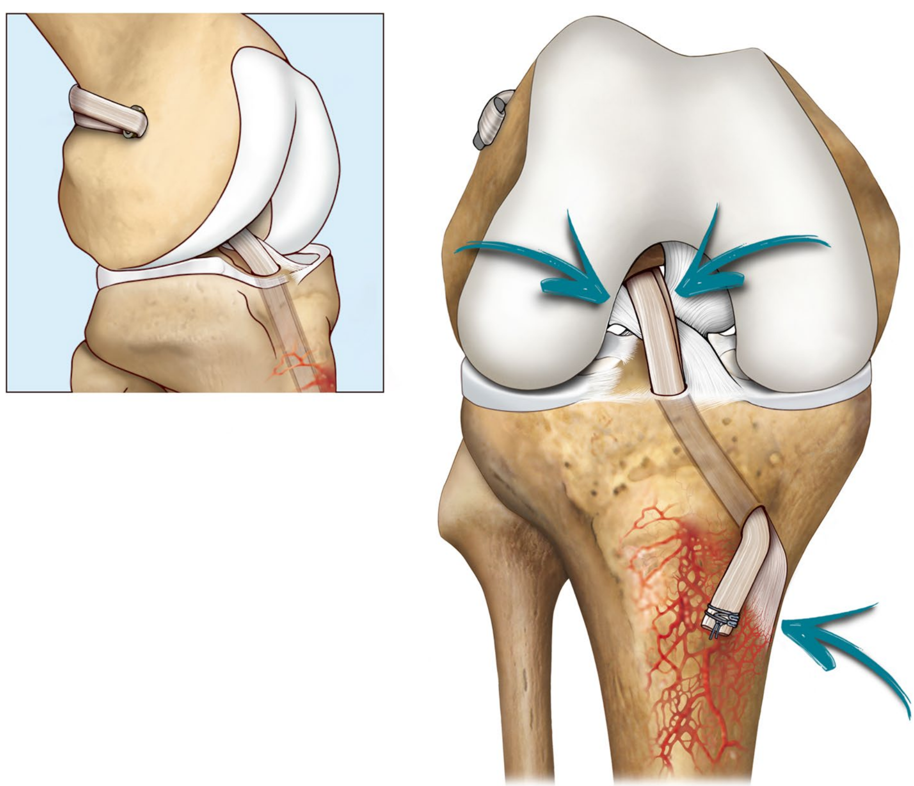

Fig. 3 Surgical technique

Removing AMT Group and at 36 and 48 months for Sparing AMT Group (91.1).

According to IKDC objective score, at final follow-up, 35 patients were rated A (18 in the Sparing AMT Group and 17 in the Removing AMT Group), 6 patients were rated B (2 in the Sparing AMT Group and 4 in the Removing AMT Group), and 1 patient was rated C (Removing AMT Group) (Fig. 6).

The best IKDC mean value for Removing AMT Group (90.1) was achieved as early as 36 months (91.1); otherwise for Sparing AMT Group, this value was maintained until the last 60-month follow-up. The best value in TEGNER score was achieved by Removing AMT Group at 60 months of follow-up (7.2), while for Sparing AMT Group it was obtained at the same follow-up of 60 months but with a higher score (7.8) (P test = 0.007); Sparing AMT Group achieved the best TEGNER value (7.4) at 48 months, whereas Removing AMT Group achieved 7.2. The percentage of improvement in TEGNER score at 60 months compared to the preoperative level for Sparing AMT Group (73.4 ± 10) was higher than Removing AMT Group (65.9 ± 8) (P test = 0.003). Independently of the technique used, return to sport activity required 6.7 months (intended as a return to the official match). In particular, this value was 7.1 months for Removing AMT Group and 6.1 months for Sparing AMT Group (Fig. 7). IKDC values did not affect the

Fig. 4 IKDC score

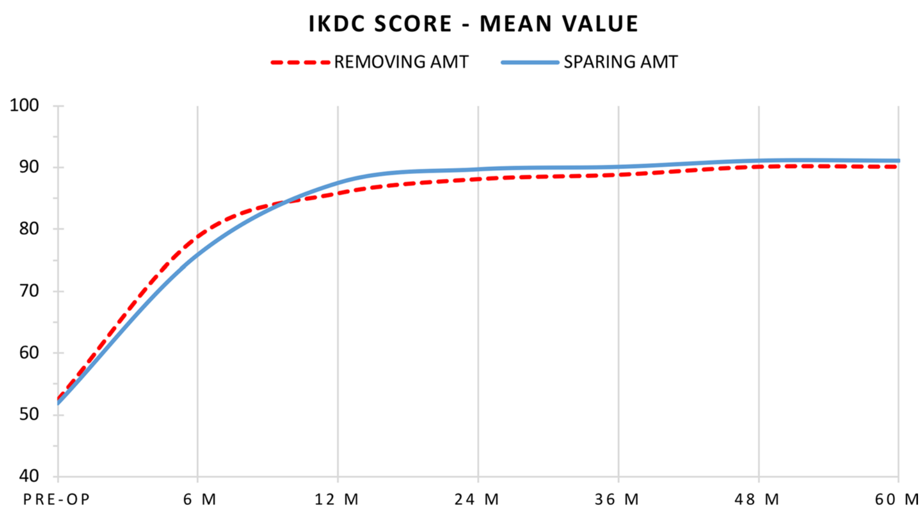

Fig. 5 Tegner score

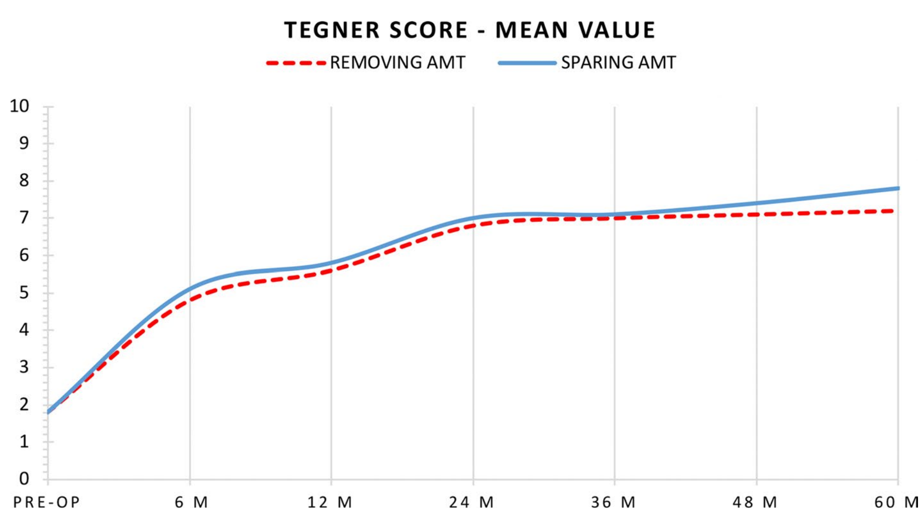

Fig. 6 IKDC objective score

		IKDC OBJECTIVE SCORE AT FINAL FOLLOW-UP			
	TOTAL	**A**	**B**	**C**	**D**
SPARING AMT	**20**	18	2	0	0
REMOVING AMT	**22**	17	4	1	0

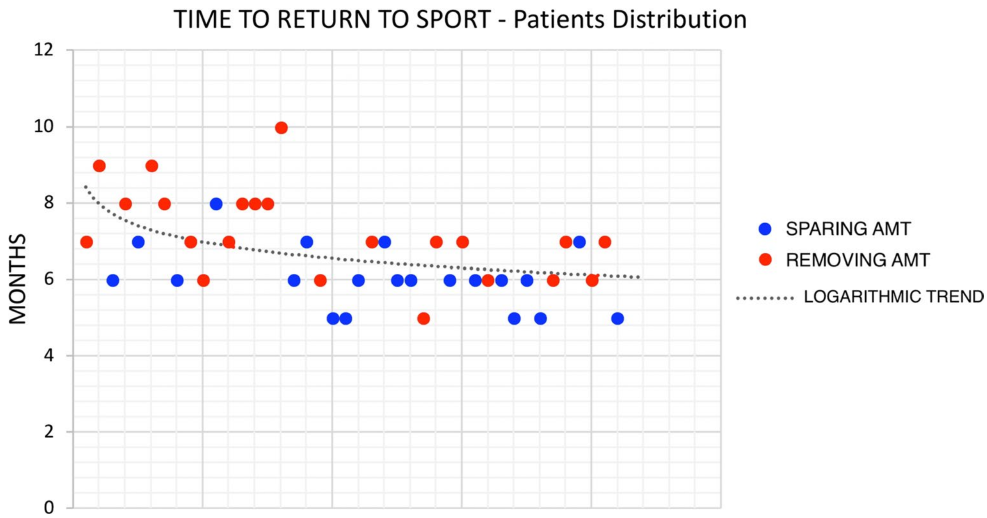

Fig. 7 Time to return to sport

time to return to sport although Sparing AMT Group showed better trend values than Removing AMT Group. As for pain perception calculated with the VAS mean score, Sparing AMT Group showed better values at 60 months (0.6), while for Removing AMT Group at 60 months the value was 1.2 although both groups started from identical preoperative baseline (8.9). The percentage of improvement in VAS score was 92.7 ± 11 for Sparing AMT Group and 87.6 ± 6 for Removing AMT Group (*P* test = 0.012). Arthrometric evaluation performed with the KT-1000 at final follow-up showed a mean side-to-side difference of 0.9 ± 1.3 mm in the Removing AMT Group and 0.8 ± 1.0 mm in the Sparing AMT Group (Fig. 8).

Discussion

In general, ACL reconstruction surgery has led to good results with relative satisfaction for the patient in terms of return to sports activity. Despite these results, some issues affected outcomes in the medium and long term in different case series with functional knee joint deficiencies [16, 34, 35]. The reasons for inferior clinical outcomes may be multifactorial but have been found to be primarily related to unsatisfactory biological healing status of grafted tendons [23, 25, 35]. It is in fact in this critical area that the spearing of ACL remnant can find its best explanation, although its salvage involves a more difficult technique for the surgeon. In fact this requires adapted portals especially in controlling the instruments during tunnel reaming and in the management of intercondylar space, which is crucial, especially in small knees. These difficulties are rewarded by results of several studies that have shown both good biomechanical stability and a satisfactory biological healing status of ACL grafts in patients after remnant preserving ACLR [2, 18, 29, 36]. Recently, histological studies have confirmed that a number of vessels and mechanoreceptors can be found within ACL, supplying a better revascularization process and better proprioceptive function of ACL grafts [5, 13, 19]. Some authors have reported that cases with a good revascularization process showed better graft incorporation results on follow-up MRI and correlated to favorable clinical outcomes [1, 28]. Moreover, our technique encompasses the retaining of HG tibial insertion that can promote a faster ligamentization process due to a preservation of the vascular network, as previously described in literature [8, 32, 39]. These two important biological incentives can result in proprioception improvement that allows a more aggressive rehabilitation program. In fact, Sparing AMT Group had better Tegner score than Removing AMT Group at every follow-up in particular at last follow-up of 60 months where a statistically significant value is found (*P* test = 0.07). Furthermore, VAS score had also shown better values at every follow-up for Sparing AMT Group, with a statistically significant result on its percentage improvement (*P* test = 0.012). These two important findings have therefore resulted in earlier return to sport activity for those patients who underwent Sparing AM Technique.

Our non-anatomical technique implies that reconstructed PL band results a little bit vertical. However, in ACL partial

Fig. 8 KT-1000 values

		KT 1000					
		POST-OP			FINAL FOLLOW-UP		
	TOTAL	0-3 mm	3-5 mm	> 5 mm	0-3 mm	3-5 mm	> 5 mm
SPARING AMT	20	17	3	0	16	4	0
REMOVING AMT	22	19	3	0	17	5	0

tears rotatory instability is often minimal or at most only a trace positive [7]. For this reason, the authors accept this drawback. Over the top, femoral passage circumscribes the major difficulties and possible complications that normally occur in the construction of the femoral tunnel when an intact ACL residue bundle is present: adaptation of portals, intercondylar space management, femoral notch impingement, impaired knee extension, cyclops syndrome and the need of precise control of reaming tools [4, 9, 11, 17, 22, 33]. This study has some limitations. First of all, it has monocentric design and the low number of patients enrolled does not allow to draw definitive findings about the studied topic. Second, it is primarily a study based on clinical results; therefore, a second-look arthroscopy to evaluate ACL remnant morphology would add important information. Third, the diagnosis of rotational instability was made without any mechanical tools, but multiple skilled surgeons had checked it clinically with Pivot shift test (R.B., C.F.) [24, 40]. Finally, although the data have been collected prospectively, it is basically a retrospective study with possible unchecked biases.

Both techniques described in this study demonstrated to be able to guarantee an optimal result. Return to pre-injury level of sport participation as soon as possible after ACL reconstruction is an important measure in determining a successful outcome. Several authors have reported ACL augmentation, but each procedure and indication were different [1, 2, 4, 6, 7, 9, 16, 20, 23, 27, 29, 33, 36, 37].

In all these studies, the key concept was that the remnants bundle would play a crucial role in knee stability and ligamentization process. Less is known about whether the preserved ACL bundle can perform the function of controlling anterior and rotational instability, but some authors reported that the anterior instability was increased after the removal of the remnant bundle; therefore, this bundle has a biomechanical effect on anterior translation [11].

Conclusions

From the clinical results obtained, we believe that if the preserved remnant is bridging the femur and the tibia anatomically and has appropriate tension, it can act as a biological support to provide the basis for better knee stability. Furthermore, preserving vascular network of HG tibial insertion can favor a faster ligamentization process. These two important biological factors can result in proprioception improvement in order to start the rehabilitative phase as soon as possible. The surgical technique used in this study has proved to be extremely useful in overcoming the well-documented difficulties of ACL reconstruction in the presence of AM intact bundle, furthermore providing two fundamental biological boosts helping the ligamentization processes of the graft. This evidence is certainly a factor to take into consideration, especially when the patient is a high demand player seeking a quick sport return. A comparative prospective study with a large cohort of patients should be performed to validate these findings.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Informed consent The study was approved by the ethics committee of the authors' institution, and all patients signed an informed consent form to participate in the study.

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