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REVIEW

Preservation of hamstring tibial insertion in anterior cruciate ligament reconstruction: a review of the current literature

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Abstract Hamstring graft (HG) used in anterior cruciate ligament (ACL) reconstruction undergoes a biological modification process called "ligamentization" in the early postoperative period that proceeds through three different phases: an early graft-healing phase with central graft necrosis, a phase of proliferation, and finally, a ligamentization phase toward the properties of the intact ACL. The fastening of this process could result in more aggressive rehabilitation protocols as well as faster sport resumption. A recent literature supports the preservation of HG tibial attachment in order to enhance "ligamentization" process. Aim of this literature review is to describe all the techniques described that spare HG tibial insertion and the obtained results in order to evaluate evidence that would substantiate the maintenance of HG tibial insertion in ACL reconstruction. A search was performed using the following keywords "ACL reconstruction" in combination with "hamstrings," "hamstrings insertion," "tibial insertion," "ligamentization," and "over the top"; 18 articles were found to be relevant. Among these, eight randomized clinical trials (RCTs) were found. The RCT analyzed presented a high number of biases regarding the analyzed topic, thus making impossible to draw definitive evidences to validate HG tibial insertion sparing in ACL reconstruction. Despite the satisfactory results in many clinical series and the promising results in anatomic and animal studies, well-designed prospective clinical trials with large cohort of patients associated with MRI evaluation are mandatory to assess the beneficial effects of HG attachment preservation in ACL reconstruction.

Keywords ACL reconstruction · Hamstrings · Tibial insertion preservation · Ligamentization · Graft biology

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Introduction

A wide range of grafts is available for anterior cruciate ligament (ACL) reconstruction. In recent years, a huge number of studies supported the use of biological grafts, mainly because of their potential remodeling and integration into the joint [1]. Bone–patellar tendon–bone graft (BTBP) has been considered for many years the gold standard in ACL reconstruction. Despite its biomechanical characteristics in terms of strength, the high rate of reported donor site pathology prompted the search for other autologous graft sources [2–6]. Hamstring tendon graft (HG) showed a high regenerative potential resulting in lower donor site morbidity with respect to BTBP [7–9]. HG also showed biomechanical features similar to those of the native ACL presenting also characteristics of strength, length, and versatility that make it suitable for different reconstructive procedures [10].

A wide number of different surgical procedures using hamstrings are described in the literature for ACL reconstruction. The majority of these procedures require the detachment of HG from their tibial insertion [11]. The detached graft is inserted through the bony tunnels or sockets, and once fixed it undergoes a remodeling process at two different sites: an intra-tunnel graft incorporation and an intra-articular graft remodeling, often referred to as "ligamentization" [12].

The "ligamentization" process has been widely investigated in a more extensive way in the animal model with respect to the human model due to obvious ethical concerns. Despite the paucity of studies dealing with this topic, it seems that graft ligamentization proceeds through three different phases: an early graft-healing phase with central graft necrosis and hypocellularity and no detectable revascularization of the graft tissue, followed by a phase of proliferation, the time of most intensive remodeling and revascularization, and finally a ligamentization phase with characteristic restructuring of the graft toward the properties of the intact ACL [12].

The possibility to fasten the ligamentization process remains a hot topic for sports medicine surgeons; in fact it could result in a reduction in the detrimental effects of the graft necrosis (and revascularization process) on the mechanical properties of the graft. This could therefore permit the adoption of more aggressive rehabilitation protocols with subsequent earlier sports resumption. Some attempts to enhance this process have been described, such as native ACL remnant preservation and platelet-rich fibrin or bone marrow-derived cell administration at the time of ACL reconstruction, but even though is a promising evidence that these procedures may represent a synergic factor in acquiring a quicker graft maturity with respect to traditional ACL reconstruction, there is no definitive proof of clinical outcome enhancement in ACL surgery [13–16].

Some authors based on anatomic and animal studies proposed to spare the semitendinosus and gracilis tendons tibial insertion in ACL reconstruction in order to maintain tendons vascular supply, therefore enhancing the "ligamentization" process [1, 17].

Aim of this paper is to review the current literature to describe all the reported techniques that spare HG tibial insertion and the obtained results in order to substantiate the maintenance of HG tibial insertion in the treatment of anterior cruciate ligament ruptures.

Materials and methods

Research strategy

A search was performed using the keywords "ACL reconstruction" in combination with "hamstrings," "hamstrings insertion," "tibial insertion," "ligamentization," and "over the top." The following databases were assessed on January 2015: PubMed (http://www.ncbi.nlm.nih.gov/sites/entrez/); Ovid (http://www.ovid.com); Cochrane Reviews (http://www.cochrane.org/reviews/); and Google Scholar. All journals were considered, but only English papers were taken into account. Two authors (AR and FT) read the abstracts and excluded the articles that were considered unrelated to the topic of the study. When the abstract was not available, the title of the paper was used to judge its relevance. A cross-referencing process was used to find further relevant publications from the retained articles. From a total number of 1,054 retrieved articles, after abstract or title page evaluation, 18 articles dealing with the searched topic were evaluated. Among these articles, one was an anatomic study, one was an animal model study, two were technical tips, six were clinical case series, and eight were randomized clinical trials (RCTs). Unfortunately, the published RCTs were not dealing only with HG tibial preservation but presented severe biases, thus making impossible to perform a systematic review.

Results

A report of available clinical RCTs is reported in Table 1.

Marcacci et al. reported their clinical results at 6.4-year follow-up in a case series of 50 athletes operated by HG-spared insertion ACL reconstruction with over the top femoral route and extra-articular plasty. According to the IKDC objective score, 92 % of the knees were rated as normal or nearly normal. Arthrometric evaluation showed an anterior displacement less than 3 mm with respect to the contralateral side in the 76 % of patients. Mean Tegner score at follow-up was 8.1. Isokinetic test for evaluation of muscular impairment showed no deficit with respect to quad and hamstring muscles [18].

Zaffagnini et al. in their comparative prospective study evaluated three different ACL reconstructive techniques at 5-year follow-up. The three techniques analyzed were BPBT, four-strand hamstrings without tibial HG insertion preservation, and HG-spared insertion ACL reconstruction with over the top femoral route and extra-articular plasty. The study demonstrated that single HG plus extra-articular plasty achieved subjective score significantly higher with respect to the other groups as well as shorter time for sport resumption. In addition, the single HG plus extra-articular plasty showed lower tibial tunnel widening with respect to the disinserted four-strand HG [19].

Buda et al. [20] used HG graft with tibial insertion preservation and over the top femoral route in the treatment of ACL partial lesions. Patients have been evaluated at 3 months, 1 and 5 years showing good or excellent results in 95.7 % of the treated cases.

Zaffagnini et al. compared two different techniques with HG insertion sparing at 3-year follow-up: the double-bundle procedure with over the top passage and femoral tunnel, and the single-strand HG plus extra-articular plasty. Double-bundle group showed significantly better results in terms of IKDC score, arthrometric analysis by means of

Table 1 Summary of all the clinical randomized clinical trials dealing with hamstring tibial insertion preservation techniques

Authors	Year	Follow-up	Number of patients	Groups	Patient evaluation	Findings
Zaffagnini et al. [19]	2006	5 years	75 patients affected by complete ACL lesion: 25 patients for each group	(1) BPBT, (2) four-strand HG with tibial detachment, (3) Single HG plus extra-articular plasty with HG tibial preservation	(1) Range of motion, (2) Return to sports, (3) Tegner scale, (4) IKDC score, (5) Tight circumference and one-leg hop test, (6) Evaluation of anterior knee pain, (7) Knee laxity evaluation—Lachman test, Anterior drawer test, Pivot shift test;—arthrometric evaluation (KT-2000), 8) X-rays evaluation—Tunnel enlargement (Peyrache score)—onset of degenerative joint disease (Ahlback score)	Group 3 superior in: (1) IKDC subjective score, (2) Sport resumption, (3) Lower anterior knee pain with respect to BPBT group, (4) Lower tunnel enlargement with respect to four-strand HG group
Zaffagnini et al. [21]	2008	3 years	72 patients affected by complete ACL lesion: 35 patients in group 1, 37 patients in group 2	(1) Single HG plus extra-articular plasty with HG tibial preservation, (2) double-bundle procedure with over the top passage and femoral tunnel with HG tibial preservation	(1) Range of motion, (2) Return to sports, (3) Tegner scale, (4) Activity-rating scale, (5) IKDC score, (6) Tight circumference, (7) Knee laxity evaluation—Lachman test, Anterior drawer test, Pivot shift test;—Arthrometric evaluation (KT-2000), 8) X-rays evaluation—Tunnel enlargement (Peyrache score)—onset of degenerative joint disease (Ahlback score)	Group 2 superior in: (1) IKDC score, (2) KT-2000 evaluation, (3) Activity-rating scale, (4) Shorter time to sport resumption
Papachristou et al. [22]	2008	19.05 months	41 patients affected by complete ACL lesion: 18 patients in group 1, 23 patients in group 2	(1) Preservation of HG central continuity, double tibial tunnel, single femoral tunnel, (2) Preservation of ST central continuity and GR tibial attachment, double tibial tunnel, single femoral tunnel	(1) IKDC score, (2) Knee laxity evaluation—Noulis Lachman test, Pivot shift test, (3) Report of any complication	No differences between the two groups
Zaffagnini et al. [25]	2011	8.6 years	79 patients affected by complete ACL lesion: 40 patients in group 1, 39 patients in group 2	(1) Single HG plus extra-articular plasty with HG tibial preservation, (2) BPBT	(1) Range of motion, (2) Return to sports, (3) Tegner scale, (4) IKDC score, (5) Evaluation of anterior knee pain, (6) Knee laxity evaluation—Lachman test, Anterior drawer test, Pivot shift test;—Arthrometric evaluation (KT-2000), 7) X-Rays evaluation—onset of degenerative joint disease (IKDC score)	Group 1 superior in: (1) IKDC objective score, (2) Pivot shift test, (3) ROM, (4) Tegner scale, (5) Sport resumption, (6) Prevention of arthritic changes
Verdano et al. [28]	2012	45 months	40 patients affected by complete ACL lesion: 20 patients in each group	(1) four-strand HG with tibial detachment, (2) Single HG plus extra-articular plasty with HG tibial preservation	(1) IKDC score, (2) Lysholm knee scoring system, (3) Tegner activity scale	No significant differences between the two groups
Buda et al. [30]	2013	5 years	56 patients affected by partial ACL lesion: 26 patients in each group	(1) ST harvested with tibial insertion preservation, tibial tunnel and femoral tunnel, (2) HG harvested with tibial insertion preservation, tibial tunnel and over the top passage	(1) IKDC score, (2) Tegner scale, (3) Arthrometric evaluation (KT-1000), (4) Report of any complication	No differences between the two groups. The reconstructed bundle significantly affected the outcome

KT-2000, activity-rating scale, and time to return to sport. No tunnel enlargement was observed in both groups [21].

Papachristou et al. compared two procedures with double tibial tunnel and single femoral tunnel. In one group, HG was harvested detaching their tibial insertion but maintaining the central continuity of the tendons, while in the other group the semitendinosus was harvested in the same fashion, and the gracilis was harvested maintaining its tibial insertion. Patient evaluation was carried out at 19.05-month follow-up. No differences were observed between the two groups [22].

Buda et al. reported the results of an MRI study in the treatment of ACL partial lesion by over the top HG reconstruction with preservation of tibial attachment. Twenty-eight patients were evaluated by MRI at 25.8-month follow-up. Tunnel widening was present in six cases. Graft appeared to be continuous in 25 patients (Yamato grade I). The intra-articular and intra-tunnel portion of the graft was normal in 20 patients (Howell grade I). Tibial attachment of HG had a normal appearance in 26 patients [23].

Marcacci et al. described the results of HG-spared insertion ACL reconstruction with over the top femoral route and extra-articular plasty in 54 athletes at 5- and 11-year follow-up. According to IKDC score, results were excellent or good in 90.7 % of the patients at final follow-up. A side-to-side difference over 5 mm was observed in only one patient at final follow-up. The onset of arthritic changes was only evident in patients who underwent concomitant meniscectomy [24].

Zaffagnini et al. [25] compared 8-year minimum follow-up BPTB reconstruction versus tibial-inserted HG reconstruction with over the top route and femoral tunnel showing better functional results and lower degenerative changes in HG group.

Zaffagnini et al., using a surgical navigation system dedicated to kinematic assessment, compared the standard clinical laxities and pivot shift tests in the operating room following ACL reconstruction by means of double-bundle anatomic technique with HG tibial detachment and single preserved insertion HG with over the top passage and extra-articular plasty. The results were similar in static knee laxity, but anatomic double-bundle reconstruction better restored the dynamic behavior of the knee [26]. The same device was employed in another study comparing non-anatomic double-bundle reconstruction with HG insertion preservation and double-bundle anatomic reconstruction with HG detachment. No differences were observed in both static and dynamic laxities between the two groups except for a larger preoperative to postoperative difference in anterior–posterior tibial plateau displacement of the medial and lateral compartments during the internal–external rotation test at 30° of flexion in the non-anatomic double-bundle group. It has been reported that non-anatomic double-bundle reconstruction required significantly lower mean surgical time with respect to the other groups [27].

Verdano et al. compared HG reconstruction with tibial insertion preservation over the top route and extra-articular plasty versus four-strand free HG obtaining comparable satisfactory results in both groups [28].

Buda et al. described their original technique to perform an anatomic ACL single-bundle reconstruction maintaining the tibial insertion of HG. The preliminary results of a case series of 57 patients evaluated at 16 ± 2.5-month follow-up showed encouraging clinical results regarding subjective and objective outcomes [29].

Another paper by Buda et al. [30] compared two different HG insertion-sparing techniques in the treatment of ACL partial lesions without any significative difference between the two groups at 5-year follow-up.

The most recent report available in the literature concerning tibial HG attachment preservation is related to a case series of 21 professional soccer players operated by non-anatomic double-bundle ACL reconstruction followed by patient-tailored rehabilitation. The procedure permitted a faster sport resumption (return to official matches 186 ± 53 days after surgery) with respect to the other case series available in the literature and dealing with top-level athletes allowing 95 and 62 % of the professional male soccer players to return to the same sport activity 1 and 4 years after surgery, respectively [31].

Discussion

The available literature is insufficient to draw definitive conclusions upon HG tibial insertion preservation. In particular, the available RCTs deal with different reconstructive techniques as well as different fixation methods [19, 21, 22, 25, 28, 30]. No prospective RCTs were found comparing two ACL reconstructive procedures with hamstrings using the same technique and fixation methods and differing only for HG attachment preservation or avulsion.

However, the philosophy of graft insertion maintenance aimed to enhance graft ligamentization appears to be fashionable. In particular, Zaffagnini et al. in their anatomic study demonstrated that PES tendon insertion is well vascularized and richly innervated and that these morphological features continue along the length of the tendons [17]. The preserved innervation of the tendons can enhance the proprioceptive recovery after ACL surgery acting as the mechanoreceptors present in the native ACL according to Shultz et al. [32]. The continuity of tendon vascularization should be important in maintaining tendon viability preventing the phase of graft necrosis, thus permitting to obtain a faster ligamentization. The maintenance of semitendinosus tendon viability by sparing its distal attachment has been demonstrated in the rabbit model by the histologic study of Papachristou et al. [1].

The techniques described in the literature preserving HG insertion showed extremely satisfactory results in all the reported case series. In particular, the results reported at more than 5-year follow-up appear to be in line or even slightly better with respect to revision rate compared with the results of the Danish registry for knee ligament reconstructions [33].

Unfortunately, it was impossible to determine the effective contribution of HG insertion maintenance on these results. We found only one available study that evaluated HG reconstruction with spared insertion by means of MRI. Unfortunately, the MRI was taken at a mean of 25.8-month follow-up, making difficult to evaluate the early phases of ligamentization process. However, the authors reported a high percentage of normal signal graft both in the tibial tunnel and in the intra-articular passage deposing for a complete maturation from the tendon tissue to a ligament-like tissue [23]. Another indirect sign of early graft integration may be represented by the absence of osteolysis or tunnel widening after ACL reconstruction with inserted HG. Marcacci et al. reported no significant tunnel enlargement at 11-year follow-up although the fixation points of the chosen reconstruction (single-strand HG plus extra-articular plasty) were distant to the intra-articular margin of the reconstruction. Clatworthy et al., L'Insalata et al., and Tsuda et al. have shown that tunnel enlargement after ACL reconstruction may be the result of windshield wiper or bungee effects associated with graft fixation distant to the joint. Marcacci et al. stated that the lack of significant tunnel enlargement at any point in their study may be the result of early graft incorporation and/or integration into the tunnel, as the fixation sites of the graft were distant relative to the joint [24, 34–36].

The same finding is evinced by the comparative study by Zaffagnini et al. in which lower tunnel enlargement with respect to four-strand HG group was observed in patients operated by single-strand inserted HG plus extra-articular plasty [19].

It has been noticed that the preservation of HG attachment presents some undoubted advantages. First of all, the length and versatility of the HG associated with the development of new fixation devices permit the surgeon to choose among several different reconstructive procedures based on its preference and background. Inserted HG can be used in non-anatomic techniques adopting the femoral over the top route eventually associated with a lateral extra-articular plasty over the Gerdy's tubercle, in anatomic single-bundle techniques drilling the femoral socket both from the AM portal and with a trans-lateral approach and even in double-bundle techniques (double tibial tunnel and femoral tunnel, single tibial tunnel with over the top route and femoral tunnel, double tibial tunnel and double femoral socket) [18–29, 31, 37]. The preservation of HG is suitable also to fix ACL partial lesions [20, 23, 30]. Secondarily, most of the techniques described require only two staples to complete the reconstructive procedure resulting in a dramatic reduction in costs [24]. Finally, it has to be considered that distally inserted HG does not need the tibial fixation which is commonly achieved by means of interference screws with reduction in costs as well as hardware-related complications on the tibial side.

On the other hand, the available literature does not allow to draw definitive conclusions about the HG tibial attachment preservation in ACL surgery. There are too many confounding biases in the RCTs available which make it difficult to determine the effective usefulness of HG insertion sparing after ACL reconstruction. In order to determine the efficacy of the investigated procedure, the focus should be directed toward the early phase of graft remodeling. Differently from the animal model, the adoption of seriate biopsies raises unacceptable ethical concerns on humans. For these reasons, the best tool available to determine the proceeding of graft ligamentization seems to be represented by MRI. Figueroa et al. [38] described a useful scoring method aimed to evaluate graft morphology and characteristic which may be useful to properly assess the graft evolution in the first 6–12 months. Randomized prospective well-designed comparative studies evaluating by MRI the early phases of graft biology are therefore mandatory in order to validate the beneficial effects of this procedure.

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

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