

Single- or Double-Bundle Technique in the Anterior Cruciate Ligament Reconstruction — Current Concepts and Review of the Literature

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ABSTRACT

The treatment for anterior cruciate ligament (ACL) deficient knee consists in its surgical reconstruction. There are several available and validated techniques, but there are still numerous questions to be answered concerning the best approach in terms of stability, functional outcome, and avoiding further damage in the knee. This paper sought to analyze the studies published in the literature comparing the outcomes of ACL restoration with single-bundle versus double-bundle techniques. The results demonstrate that even if biomechanical studies find an increased steadiness with double-bundle ACL reconstruction, there seems to be no clinical or functional benefit compared with single-bundle reconstruction.

Keywords: anterior cruciate ligament reconstruction, single-bundle, double-bundle, knee, instability, arthroscopy

INTRODUCTION

Anterior Cruciate Ligament (ACL) damage is commonly encountered in orthopedic practice. The gold standard treatment for active patients with ACL rupture consists in surgically reconstructing this ligament. The principle of this surgical intervention is to reestablish stability and function in the knee, preventing further damage of the knee joint. Present-day surgical reconstruction techniques still provide significant percentage of reconstruction failures, even if there is a significant improvement of the results. There are several technical aspects that need further analysis in order to achieve the best results, such as:

graft choice, tunnel positioning, fixation, etc. The ACL comprises two functional and anatomical bundles: the anteromedial (AM) and the posterolateral (PL) bundle. Preliminary studies conducted on cadavers suggested that the reconstruction of the two bundles supplies an improved fixation and function compared to single-bundle reconstruction.¹⁻⁴ There are some early anatomic description reports of the two bundles from Palmer in 1938,⁵ Abbott *et al.* in 1944,⁶ and Girgis *et al.* in 1975.⁷ The two bundles have different length patterns as shown in the studies of Kurosawa, Yasuda, *et al.* published in CORR in 1991,⁸ and Bach *et al.* published in the Journal of Biomechanics in 1997.⁹ The two bundles also have different stabilizing functions: the AM bundle has its primary function in limiting anterior tibial translation, and the PL bundle mostly functions as a rotational movement stabilizer, as shown by Sakane *et al.* (JOR, 1997),¹⁰ and Gabriel *et al.* in a trial published in the Journal of Orthopedic Research in 2004.¹¹ The normal function of the ACL is given by the integration of the different functions of the aforementioned two bundles.

Several published studies show controversies regarding the functional results and stability of different ACL reconstruction methods.^{12,13} The present paper tries to present an analysis of the publications on the effect of single- compared to double-bundle ACL restorations.

RESULTS AND DISCUSSIONS

The primary and most important question to answer: is double-bundle ACL reconstruction better in comparison to single-bundle? For this purpose, biomechanical, clinical and surgical technique evaluation should be performed.

Several studies are focused on the biomechanical analysis of the graft stability. Contradictory results emerge from studies published in the early 2000s. Single-bundle ACL restoration can reproduce the normal ACL tension pattern, improve the rotatory stability, and restore normal knee kinematics.¹⁴⁻¹⁶ Woo and Kanamori, in two separate studies published in 2000, showed that single-bundle reconstruction is inadequate for resisting to rotatory loads.^{17,18} A robotic analysis published by Woo in 2002 proposes that single bundle ACL restoration is not able to entirely re-establish the regular anterior laxity, or it is not efficient for the rotatory unsteadiness.¹⁹ Two other articles published by Georgoulis in 2003²⁰ and Tashman in 2004²¹ also showed that single-bundle restoration does not considerably improve the high rotatory instability that occurs upon walking (gait analysis). The study published by Woo in 2002 also shows that rotatory laxity is sensitive to the orientation of femoral graft insertion.¹⁹ This is con-

firmed by Loh in 2003, showing that laterally placed grafts have better control of rotatory loads.¹⁵ Kanaya *et al.*, in a randomized prospective study from 2009, analyzed the intraoperative stability of ACL reconstruction of a lower placed tunnel in single-bundle versus double-bundle restoration.²² They concluded that an inferior femoral tunnel replicated the anteroposterior and rotational stability in both single-bundle and double-bundle restoration. Several studies show that single-bundle ACL reconstruction results are biomechanically suitable, but “A” rank of IKDC rate is about 70%. Also, the pivot-shift was not sufficiently controlled, the control of rotation was still an issue, and 14–30% of cases were shown to have residual pivot “glide”.^{23,24}

Kondo *et al.* in 2006, searched to see if the postero-lateral bundle is indeed reconstructed after the anatomical double-bundle ACL restoration, by performing a prospective arthroscopic second-look at one year following the reconstruction procedure. One-hundred seventy-eight subjects were included in this study. The postero-lateral bundle was truly reconstructed in 96% of the patients.²⁵ Otsubo published a second-look arthroscopy study in 2007, in which he evaluated the results of anatomically reconstructed double-bundle grafts, and found that, although none of the patients had complained of subjective instability after the operation, 11% of postero-lateral grafts were substantially damaged.²⁶ These two studies show that double-bundle reconstruction restores the postero-lateral bundle of the native ACL.

Experimental biomechanical studies show that rotation is better controlled by double-bundle compared to single-bundle restoration: the implantation of multi-bundled structures provides a closer result to normal knee behavior function in load sharing;^{9,27} anatomical restoration was considerably more alike to the normal knee compared to single-bundle restoration.²⁸ A review article published in 2007 by Shen *et al.* concluded that anatomical double-bundle ACL restoration is a challenging method, although it offers better reconstruction of normal knee anatomy and function compared to single-bundle restoration.²⁹ In 2011, Plaweski published a prospective study showing that there is a higher intraprocedural improvement in anterior and rotational steadiness in case of four-tunnel double-bundle ACL reconstruction, in contrast to single-bundle ACL restoration.³⁰ In a systematic review published in 2015 by Mascarenhas it was stated that the current level of evidence suggests that double-bundle restoration provides a higher quality postoperative knee stability (KT Arthrometer) and better pivot-shift testing in contrast to single-bundle restoration.³¹ Despite this, the effect on clinical outcomes

and risk of graft failure was found to be non-significant. In 2015, Lorbach *et al.* studied cadaveric knee kinematics after ACL reconstruction, and found that anterior tibial translation, as well as anterior tibial translation in response to a combined rotatory load, was associated with a notably higher ACL damage.³² There were no significant discrepancies in knee kinetics for anatomical single-bundle and double-bundle reconstruction methods with meniscal repair in comparison with the normal undamaged knee. Another randomized prospective controlled study published by Sun *et al.* in 2015 shows that double-bundle ACL restoration increases the anterior and rotational stability, and presents a decreased progression towards arthritis and tunnel growth compared to single-bundle at 3 years after the surgery.^{33–35} In conclusion, studies have suggested that the anatomical double-bundle method could provide improved stability to ACL-deficient knees immediately after surgery. Kinematic performance was improved in cases with double-bundle ACL reconstruction.^{28,34,35}

Current studies suggest that double-bundle ACL restoration can bring back the function of the knee closer to that of a normal one, compared to single-bundle ACL restoration. An aim of ACL surgery is to restore the knee stability as close as possible to that of a normal knee joint. Is better stability a real benefit for patients? It seems that there is no real evidence for this. There might be better results concerning meniscal preservation and postoperative osteoarthritis.

Next question to answer: does the anatomical double-bundle ACL restoration have clinical benefits? Yasuda published a prospective randomized study in 2006 analyzing the anatomical double-bundle ACL restoration.³⁶ Their team found no significant dissimilarities between the anatomical double-bundle and single-bundle procedures regarding complication rate, range of movement, muscular force and the Lysholm score. The operation times were longer for double-bundle (50 min) compared to single-bundle (40 min) procedures. A systematic review on studies that compare the two techniques, published by Longo *et al.* in 2011, shows that due to the lack of sufficient data, it was not feasible to clearly recommend the systematic use of double-bundle ACL restoration.³⁷ With the current evidence available, the single-bundle technique is considered an appropriate method, and it should not be discarded. Gobbi *et al.*, in a study from 2012, analyzed the variation in stability and function during the 3-year follow-up between the two techniques, and found that double-bundle restoration of the ACL did not lead to a better function or stability in contrast with single-bundle restoration.¹² In 2012, Nunez published a randomized trial analyzing the quality

of life and costs for double-bundle and single-bundle ACL restoration, and concluded that the quality of life related to physical condition and medical results were similar between the two reconstruction techniques, during the 2-year postoperative follow-up.³⁸ Despite this, the single-bundle method was more cost-efficient. A meta-analysis of 19 randomized controlled trials looking for outcomes of ACL restoration using single-bundle versus double-bundle methods, published by Xu *et al.* in *Arthroscopy* in 2013, concluded that double-bundle restoration showed improved anterior and rotational stability, and higher IKDC objective scores when compared with single-bundle restoration.³⁹ Nevertheless, this meta-analysis could not find significant variations between the two methods regarding the subjective measurements of the postoperative results, illustrated by the Lysholm score, the Tegner activity scale and the IKDC scale. Lin Li *et al.* published a meta-analysis on single-bundle or double-bundle techniques for ACL restoration that proved the superiority of double-bundle, with higher improvement in rotational laxity for pivot-shift, KT Arthrometer and the IKDC score.⁴⁰ Nonetheless, regarding functional recovery, there was no significant difference between the two ACL reconstruction methods. Another study on randomized controlled trials published in 2015 by Chen, concluded that double-bundle ACL restoration effectively enhances rotational steadiness of the knee and achieves higher subjective functional scores during the mid-term follow-up compared to the single-bundle procedure.⁴¹ However, during the long-term follow-up, the results regarding knee joint stability must be interpreted with caution.

When comparing the two techniques, one should analyze if the anatomical double-bundle ACL restoration provides technical difficulty. There are no comparative studies to answer this question, but it is obvious that the double-bundle technique is more challenging than single-bundle, and it is essential to precisely create two tunnels both in the tibia and the femur. Several studies recommend the double-bundle technique only for experienced surgeons. Nevertheless, Yasuda reported no complications after 300 consecutive double-bundle ACL reconstructions.⁴² Järvelä compared the two techniques, and concluded that double-bundle provides higher rotational steadiness of the knee on a short-term period.⁴³ The double-bundle method is more difficult, and has more chances to give technical failures. It may be recommended for subjects who are performing challenging pivoting sports. Wolf, in a study published in *KSSTA* in 2015, shows that a lower intercondylar notch dimension does not provide higher risk for graft failure after anatomical ACL restoration.⁴⁴ Based on these results, the

use of notchplasty is not recommended. The meta-analysis published by Desai *et al.* in 2014 found that anatomical double-bundle is better compared to single-bundle in terms of re-establishment of knee kinetics and primary anteroposterior laxity.⁴ It remains uncertain whether this increased laxity leads to long-term improvement. A comprehensive systematic review published by Björnsson in KSSTA in 2015 shows that double-bundle ACL restoration appears to have lesser re-ruptures and decreased anteroposterior rotatory laxity, but there is no difference in short-term follow-up in objective findings regarding muscular force and range of movement.⁴⁵ In 2016 Desai published a systematic review in KSSTA analyzing the two techniques using a scoring checklist. The conclusion was that it is difficult to achieve objective data, and that there was a considerable underreporting of surgical information from the two groups.⁴⁶

There is no objective data showing the clinical superiority of double-bundle as compared to single-bundle ACL restoration.

In conclusion, can we say that less is more? The anatomical single-bundle ACL reconstruction restores the kinematics of the knee joint with good and reproducible clinical results, it is less demanding technically, with shorter operation time, easier revision, and it is less expensive. The disadvantages of the double-bundle method include the number of tunnels, the fact that it is more expensive, it needs four fixation points, longer operative time, can produce femoral condyle osteonecrosis and chondrolysis, it is more demanding technically, it needs an experienced surgeon, and the revision procedure is more difficult. So, why should someone perform a double-bundle ACL restoration? There is limited data in the literature showing worse results of anatomical double-bundle compared with anatomical single-bundle ACL restoration regarding stability, clinical outcome and progression to osteoarthritis. Therefore, it is not a bad procedure. It seems that two bundles are better than one in the attempt to recreate the normal anatomy. Double-bundle can restore the “near normal” knee stability compared to single-bundle. There are also small clinical advantages for double-bundle in comparison to single-bundle in terms of steadiness and avoidance of osteoarthritis. It is difficult to objectively measure clinical differences between the two techniques. Suomalainen *et al.* published a study in 2012 and found that knee stability and osteoarthritis were similar after 5 years.⁴⁷ Another study published by Song *et al.* in 2013 concluded that the double-bundle technique compared to single-bundle is not more effective in the prevention osteoarthritis, and did not have a favorable outcome after a follow-up of mini-

mum 4 years.⁴⁸ There is no data in the literature sustaining that double-bundle provides better protection of menisci and prevention of osteoarthritis.

Also, there is no consensus in the literature about the indication of single-bundle or double-bundle technique, and it is considered a “surgeon’s option”. We really don’t know if the anatomical double-bundle reconstruction can provide any real benefits for subjects with damaged ACL, and if the higher surgical difficulty and revision potentially validate its benefits. Further clinical studies are needed to conclude the utility of double-bundle ACL restoration. Much remains unknown: is it effective for rotatory instability? Are functional results better in the long-term follow-up? What are the indications? Are there any problems in revision surgery? Is there a real risk for graft impingement?

CONCLUSIONS

The anatomic double-bundle procedure is one of the surgical options to treat the ACL-deficient knee if well-trained knee surgeons perform it. Published randomized controlled trials have yet failed to show a major clinical difference between double-bundle and single-bundle ACL restoration.

CONFLICT OF INTEREST

Nothing to declare.

ABBREVIATIONS

ACL	anterior cruciate ligament
AM	anteromedial bundle
PL	posterolateral bundle
ROM	range of motion
IKDC	International Knee Documentation Committee knee ligament outcome guide

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