

Clinical Faceoff

Single- Versus Double-bundle Anterior Cruciate Ligament Reconstruction

Robert G. Marx MD, MSc, FRCSC

For this inaugural Clinical Faceoff, I have invited two internationally known experts on anterior cruciate ligament (ACL) reconstruction to discuss two approaches: single- and double-bundle

reconstruction. Russell Warren, MD, is the Surgeon-in-Chief Emeritus at Hospital for Special Surgery and a past president of the American Orthopaedic Society for Sports Medicine (AOSSM) and American Shoulder and Elbow Surgeons. Joining Dr. Warren and me is Freddie Fu, MD, the David Silver Professor and Chairman of the Department of Orthopaedic Surgery at University of Pittsburgh and past president of AOSSM and the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine. There is great controversy in this area, and the discussion between these two experts addresses the key issues.

Robert Marx MD: *Should double-bundle ACL reconstruction be used for all primary cases?*

Russell Warren MD: A definitive study is still needed to determine whether primary ACL reconstruction should be performed with a double-bundle technique instead of a single-bundle approach. To date, multiple studies have shown improvements in rotational control with a double-bundle approach, but the clinical relevance of this is unclear as many studies have failed to demonstrate significant differences on important parameters. Recently, Dr. Irrgang et al. [6] indicated that “at this time, there is no definitive

evidence that double-bundle ACL reconstruction is better than single-bundle ACL reconstruction in terms of measures of knee joint structures, functions, and clinical outcomes.” They proposed an NIH-funded study in an attempt to answer this question. I have found single-bundle reconstruction to be of value to my patients over many years. Bone-patellar tendon-bone autograft can be used for a single-bundle reconstruction, allowing for bone-to-bone healing and aperture fixation. The double-bundle technique typically uses “suspensory” fixation, leading to increased creep and potential tunnel widening.

Anatomic reconstruction with the double-bundle technique leads to the two bundles functioning somewhat independently at different degrees of knee flexion, potentially placing the entire load on a smaller graft (bundle). If single-bundle ACL reconstruction is performed, it must be placed anatomically so the change in length with flexion is minimal, as observed in a normal ACL. Graft tunnel location is critical to both techniques. Using intraoperative computer navigation, we found that some knees have higher degrees of rotation after ACL injury [2]. These knees may be better served by a double-bundle approach. Further

Note from the Editor-in-Chief: We are pleased to introduce readers of Clinical Orthopaedics and Related Research® to Clinical Faceoff, a new regular feature. This section is a point-counterpoint discussion between recognized experts in their fields on a controversial clinical or nonclinical issue. We welcome reader feedback on all of our columns and articles; please send your comments to eic@clinOrthop.org.

The author certifies that he, or a member of his immediate family, has no funding or commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request.

The opinions expressed are those of the writers and do not reflect the opinion or policy of *CORR*® or the Association of Bone and Joint Surgeons®.

R. G. Marx (✉)
Sports Medicine and Shoulder Service,
Hospital for Special Surgery, 535 East
70th Street, New York, NY 10021, USA
e-mail: marxr@hss.edu

Clinical Faceoff

research is necessary to make a definitive conclusion. Both techniques have been shown to have high success rates if performed well.

Freddie Fu MD: We use the “double-bundle concept” when approaching all primary ACL reconstructions. This concept demonstrates awareness that the native ACL consists of both anteromedial and posterolateral bundles, and when reconstructing the ACL using either a single-bundle or double-bundle technique, it is imperative to keep in mind the location and functions of both of these bundles. There are scenarios for which we feel patients are not candidates for double-bundle reconstruction, such as those with either narrow notch widths or shallow notch heights. We prefer to individualize each patient based on both anatomical and graft considerations, and we do not use a “one size fits all” philosophy.

As Dr. Warren mentioned, we are currently conducting an NIH-funded, prospective, randomized trial comparing both single- and double-bundle ACL reconstructions. This trial has strict inclusion and exclusion criteria that we feel will capture the majority of the ACL-injured population and make the outcomes quite relevant. Together with Drs. Irrgang and Tashman we are assessing postoperative outcomes using highly sophisticated in vivo, biodynamic measurements and advanced imaging [6]. The results of

this study should enable us to help answer the question of primary single-versus double-bundle reconstruction use in the near future.

Dr. Marx: *Does double-bundle ACL reconstruction result in fewer clinical failures than single-bundle ACL reconstruction?*

Dr. Fu: Unfortunately, there is not a simple answer to this question. The first consideration is whether the graft is placed anatomically or not. The traditional single-bundle technique typically places the graft in the so-called “posterolateral to high anteromedial position.” In this position, the graft does not sustain the same amount of forces as the native ACL, which may be directed through other surrounding structures, such as the condyles, menisci, and collateral ligaments. Therefore, an anatomically placed graft may actually be prone to relatively higher failure rates as a result of higher in situ forces [7].

As mentioned, both the anatomic single- and double-bundle techniques have their own individual indications and contraindications. A surgeon should master both techniques and apply either one depending on the anatomical characteristics of each patient. Double-bundle ACL reconstruction should be regarded as a concept rather than as an actual “technique.” Recently, we have published a Level I study that reported on anatomic double-bundle

being significantly superior to conventional single-bundle ACL reconstruction and better than anatomic single-bundle reconstruction when the groups were randomized [5]. A succeeding study that individualized the single- and double-bundle techniques to their particular indications found equal outcomes for both techniques [4].

Typically, a tibial insertion site length of less than 14 mm is an indication for a single-bundle reconstruction. When the tibial insertion site is greater than 14 mm, either single-bundle or double-bundle reconstruction can be performed, and a double-bundle is the preferred technique in cases with a tibial insertion site size of greater than 18 mm in length [11]. If either technique is used for the wrong indication, early clinical failure may be the result.

Regardless of the technique performed, all grafts need time to heal. In this regard, a double-bundle graft theoretically may prove weaker in the early phase after surgery until the bundles heal together and facilitate their synergistic effects. Additionally, because double-bundle reconstruction is technically a more demanding procedure with a learning curve, the clinical failure rate may be somewhat higher in inexperienced hands; however, this should not discourage surgeons from learning this technique, as mastering both techniques and utilizing them in the appropriate scenarios will provide

Clinical Faceoff

patients with the best potential for successful outcomes.

Dr. Warren: In reading Dr. Fu's response to this question, several issues are noted. First, most anatomic single-bundle techniques appear higher on the wall than that noted in Fig. 2 of the article by Hussein et al. [4]. The issue of going lower on the wall can be overdone, as the graft becomes less of an anterior bundle and more posterior lateral. A single graft that is low on the wall will function only near extension or at 0°, and the forces on the graft may be excessive if fixed in flexion.

The authors comment that a double-bundle technique is indicated if the tibial footprint is greater than 18 mm. Actually, in their article comparing anatomic single-bundle and anatomic double-bundle techniques, they used a 16-mm cutoff and noted they were equal in outcome, but the authors did not perform an anatomic single-bundle with the larger tibial footprint, making it hard to accept a tibial footprint of greater than 16 mm as a reason to do a double-bundle ACL reconstruction.

They also note that a double-bundle technique may need longer to heal together and act synergistically. To my knowledge, it has not been proven that there is a shared load between the two grafts, as opposed to a larger single-bundle where the collagen is interconnected and loads can be shared. Lack of graft interaction is one of

my concerns with a double-bundle technique.

Dr. Marx: *Is revising a double-bundle ACL reconstruction more technically difficult than revising a single-bundle ACL reconstruction?*

Dr. Warren: Revising a double-bundle ACL reconstruction generally involves increased technical difficulty compared to revising a single-bundle reconstruction, depending on the reason for failure, the primary graft, and its fixation. Double-bundle reconstructions are typically fixed by cortical (suspensory) fixation using hamstrings. Tunnel widening has been noted more with suspensory fixation than with aperture fixation. This has been described as the "bungee-cord effect." Tunnel widening can lead to technical complexity in revision surgery, particularly if the two tunnels coalesce and leave a large cavity on the femoral side. In some cases, tunnel widening may require a two-stage revision with bone grafting. Furthermore, tunnel location is important, and bone loss following double-bundle surgery can make anatomic reconstruction more challenging. If the anteromedial bundle was well-placed and the tunnel was not enlarged, a single-bundle bone-patellar tendon-bone revision graft may be adequate; however, if the tunnels are enlarged to 15 to 20 mm or if the tibial tunnel is posterior, a two-stage procedure with bone grafting may be indicated.

Our experience with revision following failed double-bundle reconstruction is limited, as few surgeons use it as a primary procedure in our region. Revision failure rates with single bundle average approximately 20% in one series, as well as in our own study [1, 9]. A question that remains to be answered is whether double-bundle reconstruction is indicated for high-risk patients who have failed primary ACL reconstruction.

Dr. Fu: Dr. Warren's response to this complex question is well-stated. Revision of a double-bundle reconstruction can be challenging, but we feel that for every scenario there are many potential options. Tunnel widening does make revision surgery more challenging, but we have rarely seen this complication since we have been performing anatomic primary double-bundle ACL reconstructions. Although the "bungee-cord effect" can cause tunnel widening, as we showed in our 1997 study [8], this only seems to occur when using soft-tissue grafts combined with nonanatomic reconstructive techniques. I would also emphasize that the use of cortical suspensory fixation has significant advantages, as it does not interfere with the intratunnel healing process and allows the graft to heal in the same position as the native ACL.

An alternative to the use of soft-tissue grafts for double-bundle reconstruction is a quadriceps tendon autograft with a

Clinical Faceoff

bone block on the femoral end, with the soft tissue split into two bundles in the tibial tunnels. When revising patients who had quadriceps tendon autografts, we are frequently able to reuse the existing tunnel or convert to an “over-the-top” reconstruction. In our experience, bone grafting is rarely necessary, as we can use cortical fixation or fixation over a post in these revision cases.

In order to avoid revision surgery, it is important to note that primary double-bundle reconstruction requires surgical skill and experience. We urge surgeons to first fully master the single-bundle technique before attempting a double-bundle reconstruction. Also, by investigating healing after ACL reconstruction and delaying return to sports for 9 to 12 months postoperation, perhaps we can decrease the number of ACL revisions in the future.

Dr. Marx: *Will double-bundle ACL reconstruction result in less knee osteoarthritis (OA) than single-bundle reconstruction?*

Dr. Fu: Both functional bundles of the ACL should be reconstructed to adequately restore the native knee kinematics and, thus, protect the knee from degenerative changes over time. To this end, the graft(s) should mimic the native ligament with regard to size, shape, and orientation. A double-bundle technique inherently restores both of the functional bundles by reconstructing them separately, but a single-

bundle reconstruction can be carried out according to the same principles. By orienting the single-bundle graft in the same fashion as the ACL, the designated anteromedial and posterolateral sections will adapt the function of each respective bundle.

If the graft is placed nonanatomically, the normal knee kinematics will not be restored, and the injured knee will be susceptible to the development of degenerative changes [10]. Nonanatomical graft placement has been shown to decrease the thickness of the articular cartilage when compared to anatomic graft placement [3]. Again, it is of the utmost importance to employ the appropriate technique for the right indication. With either technique, we aim to reconstruct at least 60% to 80% of the native insertion sites of the ACL; however, to date, it remains unknown as to the exact percentage that should be reconstructed to sufficiently restore the normal kinematics of the knee.

We believe that this question is very relevant. Differences in knee kinematics between the two techniques (employed for the same indication) may be minimal, but over time these minimally altered kinematics have the potential to cause degenerative changes in the knee. Rather than aiming to return patients to play and settle with a stable knee with clinical examination, we should aim for the best long-term

outcomes for our patients, and ensure that the knee is restored as closely as possible to the native situation.

Dr. Warren: While restoring knee kinematics to a greater degree with the double-bundle approach may make intuitive sense, there is no evidence to date that demonstrates less OA in these patients. Perhaps this will be noted over 20 years, but the meniscus status will likely outweigh the subtle improvement in rotational control with a double-bundle approach. Dr. Fu’s approach is to mimic the anatomy closely, but if the position overstrains the graft with excess elongation (> 10%), graft failure may occur.

Dr. Fu has drawn our attention to the anatomy of the ACL, which has helped all of us. A double-bundle reconstruction, however, as currently performed, may place excess strain on parts of the graft. Until we have truly anatomic replicas of the ACL, this will be an issue.

Dr. Marx: *To summarize what I have learned from Drs. Fu and Warren, we do not yet know if double-bundle ACL reconstruction will result in fewer failures. Double-bundle ACL reconstruction has been shown in vitro to better restore knee kinematics; however, it will be some time before we know if this translates to less OA in patients in the long-term. Revision of double-bundle ACL reconstruction can have additional challenges. But, as*

Clinical Faceoff

always, there are strategies to facilitate revision. Lastly, it remains unclear whether double-bundle ACL reconstruction should be used for all primary cases. Dr. Fu's "double-bundle concept" has improved our approach to primary ACL reconstruction, and we all look forward to his prospective, randomized trial that compares the two techniques. That study should add some clarity to this complex clinical issue.

References

1. Battaglia MJ, Cordasco FA, Hannafin JA, Rodeo SA, O'Brien SJ, Altchek DW, Cavanaugh J, Wickiewicz TL, Warren RF. Results of revision anterior cruciate ligament surgery. *Am J Sports Med.* 2007;35:2057–2066.
2. Bowers A, Bedi A, Lipman JD, Potter HG, Rodeo SA, Pearle AD, Warren RF, Altchek DW. Comparison of anterior cruciate ligament tunnel position and graft obliquity with transtibial and anteromedial portal femoral tunnel reaming techniques using high-resolution magnetic resonance imaging. *Arthroscopy.* 2011;27:1511–1522.
3. Garrett W. The Effects of Graft Placement on Cartilage Thickness after ACL Reconstruction. Paper presented at: the Annual Meeting of the Orthopaedic Research Society, February 2012; San Francisco.
4. Hussein M, van Eck CF, Cretnik A, Dinevski D, Fu FH. Individualized anterior cruciate ligament surgery: a prospective study comparing anatomic single and double bundle reconstruction. *Am J Sports Med.* 2012;40:1781–1788.
5. Hussein M, van Eck CF, Cretnik A, Dinevski D, Fu FH. Prospective randomized clinical evaluation of conventional single bundle, anatomic single bundle, and anatomic double bundle anterior cruciate ligament reconstruction: 281 cases with 3- to 5-year follow-up. *Am J Sports Med.* 2012;40:512–520.
6. Irrgang M, Tashman S, Moore C, Fu FH. Challenge accepted: description of an ongoing NIH-funded randomized clinical trial to compare anatomic single bundle versus anatomic double bundle ACL reconstruction. *Arthroscopy.* 2012;28:745–748.
7. Kato Y, Ingham SJM, Kramer S, Smolinski P, Saito A, Fu FH. Effect of tunnel position for anatomic single bundle ACL reconstruction on knee biomechanics in a porcine model. *Knee Surg Sports Traumatol Arthrosc.* 2010;18:2–10.
8. L'Insalata JC, Klatt B, Fu FH, Harner CD. Tunnel expansion following anterior cruciate ligament reconstruction: a comparison of hamstring and patellar tendon autografts. *Knee Surg Sports Traumatol Arthrosc.* 1997;5:234–238.
9. Noyes FR, Barber-Westin SD. Anterior cruciate ligament revision reconstruction: results using a quadriceps tendon-patellar bone autograft. *Am J Sports Med.* 2006;34:553–564.
10. Tashman S, Collon D, Anderson K, Kolowich P, Anderst W. Abnormal rotational knee motion during running after anterior cruciate ligament reconstruction. *Am J Sports Med.* 2004;32:975–983.
11. van Eck CF, Lesniak BP, Schreiber VM, Fu FH. Anatomic single- and double-bundle anterior cruciate ligament reconstruction flowchart. *Arthroscopy.* 2010;26:258–268.