



Anatomical Double-Bundle Anterior Cruciate Ligament Reconstruction: The Chinese Experience

Wei Lu, MD,^{*} Juan Wang, MD,[†] Rui Wang, MD,[‡] Biao Chen, MD,[§]
Weimin Zhu, MD,^{*} and Freddie H. Fu, MD^{||}

The double-bundle (DB) anterior cruciate ligament (ACL) reconstruction has evolved gradually and got nationwide attentions in China for 13 years. This review summarizes the experiences we have achieved since the DB ACL reconstruction was started in our country in 1998, regarding choice of grafts, surgical approach, bone tunnel placement, and fixation methods. A growing number of articles reveal that DB ACL reconstruction brings better clinical outcomes regarding the results of KT-1000, pivot-shift, and Lachman tests, International Knee Documentation Committee (IKDC) outcomes, and complications. Superiority of knee stability after the DB compared with that after the single-bundle procedure was clarified by the randomized controlled trial. Currently, there is consensus in China that DB reconstruction is an attractive option when pursuing a better outcome for patients. Meanwhile, individualization is essential and cannot be ignored with respect to choice of grafts, surgical approaches, tunnel placement, and grafts fixation.

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Introduction

The primary objective of anterior cruciate ligament (ACL) reconstruction is committed to restore the knee functions as much as possible. Because single-bundle (SB) protocol cannot completely reconstruct the anatomy of the native ACL as the researchers proposed, double-bundle (DB) ACL reconstruction using a 2-strand semitendinosus and 2-strand gracilis

tendon was started in our country in April 1998 by Huang et al.¹ Currently, even a growing number of studies suggest that DB ACL reconstruction is gaining popularity due to its ability to restore close-to-normal knee kinematics. However, the DB ACL reconstruction surgery showed no better results during the initial period. Fortunately, the Chinese surgeons endeavor to develop new procedures to achieve better outcomes through anatomical and biomechanical studies of ACL.

Anatomy

Anatomical DB ACL reconstruction procedure was established based on the DB concept that relies on the native functional anatomy of the 2 distinct bundles of the ACL. The DB concept has been widely recognized and studied among Chinese orthopaedic surgeons over recent years. Numerous researches revealing the anatomical characteristics of the ACL in Chinese population have been published, aiming to develop surgical skills regarding the tunnel position, size, and orientation.

^{*}Department of Sports Medical, The First Affiliated Hospital of Shenzhen University (Shenzhen Second People Hospital), Shenzhen, Guangdong Province, P.R. China.

[†]Department of Joint Surgery, Third Hospital of Hebei Medical University, Shijiazhuang, Hebei, P.R. China.

[‡]Department of Orthopedics, Jiangsu Province Hospital, Nanjing, Jiangsu, China.

[§]Department of Orthopaedic Surgery, Zhongnan Hospital, Wuhan University, Wuhan, Hubei, China.

^{||}Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, PA. Address reprint requests to Freddie H. Fu, MD, Department of Orthopaedic Surgery, University of Pittsburgh, 3471 Fifth Ave, 1010 Kaufmann Building, Pittsburgh, PA 15213. E-mail: ffu@upmc.edu

Researchers acquired the anatomical parameters of the ACL from observing and measuring either fresh frozen or embalmed adult cadaveric knee joints aging from 25-94 years.²⁻¹⁰ Two functional bundles were identifiable in 86.7%-100% of the object of study.^{2-7,10,11} The tibial attachment of ACL is oriented in an oblique direction from anteromedial (AM) to posterolateral (PL) (53.85%) or from anterolateral to posteromedial (11.54%), or in a vertical direction from anterior to posterior (34.64%); the femoral attachment is oriented mainly from anteroinferior to posterosuperior (80.77%) with 90° knee flexion.⁵ The tibial insertion has an irregular shape with an arc-shaped area of central dense fibers surrounding the anterior horn of lateral meniscus and peripheral loose fibers partially blending into the anterior horn of lateral meniscus.² The femoral insertion is outlined anteriorly by the resident's ridge, the incidence rate of which was reported to be 69.23%-100%, and divided into 2 bundles by bifurcate ridge with an incidence rate of 50%-62%.⁵⁻⁹

Anatomical measurements of footprints of the ACL and its 2 bundles varied widely among studies, because of the different descriptions of the parameters and methods of measuring that were used. However, there is no apparent difference in the anatomy of ACL between Chinese and other populations according to already published articles.^{2,4-6,12-14} Zhao and Huang¹⁵ found that different starting point of separation along the septum between bundles resulted in different percentage of AM bundle relative to total ACL. Chen et al⁵ suggested to define the lengths, widths, and centers of the 2 bundles based on their respective longitudinal axes instead of the anteroposterior or longitudinal axis of the whole ACL footprint.

Some authors have investigated several landmarks and angles on the lateral intercondylar wall to locate the femoral tunnel. Li et al⁸ categorized the shape of the lateral intercondylar wall into 3 types—triangle, intermediate, and trapezoid, and found significant differences in femoral footprint angle (the angle between the longitudinal axis of ACL footprint and femoral shaft) among the 3 types (28.6°, 19.8°, and 5.3°, respectively). Luo et al⁷ reported that the center of PL bundle located at the midpoint between the anterior and posterior cartilage margins and 5 mm superior to the distal cartilage margin; the center of AM bundle located approximately at the posterior one-third between anterior and posterior cartilage margins and 9 mm superior to the distal cartilage margin while the knee was flexed at 90°.

In recent years, plenty of 3-dimensional anatomical data has been collected via computed tomography and magnetic resonance imaging examination of Chinese adult healthy volunteers. Males were reported to have significant greater long axis of femoral footprint, distance to the posterior cartilage margin, distance to the distal cartilage margin, and distance between DB centers than females did.¹⁶⁻¹⁸

Based on the observation that ACL-deficient knees frequently degenerate, the authors hold an active opinion on diagnosis and surgical reconstruction. In the acute phase of ACL injury, patients suspected with ACL injuries are recommended to get an imaging examination as pain and swelling could make it difficult for surgeons to diagnose accurately. In subacute phase, the accuracy of physical examination

improves greatly. Once the diagnosis of ACL deficiency is confirmed, patients should be given positive symptomatic treatment, muscle strength training, and sent to surgery as soon as effusion disappears and range of motion of knee joint approaches reference range. However, the most significant factor in determining the timing of surgery is the capacity to obtain full knee extension. Most respondents rated the degree of knee effusion, time elapsed since injury, pain, and strength of quadriceps muscle as somewhat significant factors. The desire to return to competitive sports was the least important factor.

Change in Surgical Approaches From 1998-2011

Most of Chinese surgeons attempt to conduct the DB procedure using the anterolateral and AM portals. The advantages of this 2-portal approach are relatively less invasive and easier to learn. However, sometimes especially when the intercondylar notch is narrow, the exposure of the femoral insertion is not sufficient. Based on these 2 portals, some surgeons also use the tibial tunnel as a portal to drill the femoral tunnel, whereas some surgeons adopt the additional central portal proposed by the coauthor Freddie Fu, which could provide better visibility particularly of the femoral footprint.

For those advocators of 2-portal technique, additional tissue injury and the necessity related to the third portal are still their main concerns. However, there is no doubt that the additional anterior portal is capable to facilitate visualization of the whole ACL, thus greatly benefiting the individualized ACL reconstruction.

Change in Choice of Grafts From 1998-2011

The most used grafts can be classified roughly into autografts, allografts, and biomaterials.¹⁹⁻²³ As for the autografts, the bone-patellar tendon-bone (BTB) is the most popular choice for many western surgeons because the length and strength of the middle one-third of the BTB are very similar to the ACL. Besides, with 2 bone blocks on both sides, there is more potentiality for the healing between the grafts and the bone. However in China, most surgeons would like to use the hamstring as the autografts.²³

At the beginning, Huang et al¹ firstly performed arthroscopic DB ACL reconstruction with hamstring tendons (gracilis and semitendinosus) from April 1998 to May 2000. In his study, 12 patients in total underwent DB ACL reconstruction, which were followed up for more than 18 months. These patients received satisfying dynamic stability and functional recovery of the knee joint accounted for 91.7%.

In the years 2003-2008, Lixian Zhu²⁴ also performed arthroscopic ACL reconstruction with hamstring tendons (gracilis and semitendinosus). In his study, 108 patients (DB 50 and SB 58) in total underwent DB ACL reconstruction, which were followed up for more than 2 years. The Results

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