

## REVIEW ARTICLE

# Anterior cruciate ligament (ACL) surgery - past, present and future

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### Abstract

Anterior cruciate ligament (ACL) injury is a common reported injury in an athlete. Historically, with the first description of the structure of ACL in 150 AD, the surgical repair and reconstruction techniques have evolved. Over the years the ACL surgery was done as direct repair, reconstruction, anatomical repair, intra-articular repair and extra-articular repair. This narrative review will discuss the different modes and techniques used for surgery chronologically, the challenges and outcomes with regard to the surgery, and the latest techniques used to improve patient outcome.

### Introduction

Ligamentous injury in the athlete is a major cause of morbidity and time away from sport [1]. The ligamentous sporting injuries in the knee are the leading cause of sport-related surgery [2] and can have devastating consequences on the sporting career of athletes. Anterior cruciate ligament (ACL) injuries account for anywhere between 25 and 50% of ligamentous knee injuries and are more common and gradually increasing in numbers [3]. It has been estimated with a prevalence of 1 in 3000 in the United States (greater than 120 000 cases annually) [4]. ACL injury is important because of increasing number and also the sequelae of the injury. Complete rupture of the ACL has a very poor potential to heal on its own [5]. ACL deficient knee will lead to meniscal damage and articular cartilage damage leading to premature onset of degeneration of the knee joint. Unfortunately, ACL repair or reconstruction cannot prevent premature degeneration, but can only achieve a stable joint in the short term and postpone the onset of arthritis [6] by about 10 years.

### Diagnosis of ACL injury

ACL injury is diagnosed by history, clinical examination and radiological imaging.

First identification and description of ACL ligament is attributed to Claudius Galen (150 AD), a Greek physician in the Roman Empire [7]. In 1845, Amedee Bonnet of Lyon described a patient who developed a "Popp" sound, and swelling of the knee. It was attributed to a torn ACL. Thirty years later Georges Noulis from Greece demonstrated that anterior subluxation of knee could cause ACL rupture in a series of cadaver studies [8]. In 1879, Paul Segond attributed a small fracture of the tibial plateau associated with ACL injury [9].

Since it was noticed that untreated ACL injury causes premature joint degeneration, instability, and meniscus and cartilage damage; the surgical treatment emerged.

### Historical background of different techniques used for ACL surgery

#### Primary repair

First attempt of ACL repair was attributed to A.W. Mayo Robson in 1895 then Ivan Palmer in 1938, and O' Donogh in 1950s reported their techniques of ACL repair through tunnels in the tibia and femur [10]. Later Marshall, Warren, Wickewicz published their results of ACL repair [7]. In 1987 Sandberg published a prospective trial on ACL repair. All these techniques emphasized early repair and immobilization of the joint. In the 1980's repair technique continued. Odensten reported outcomes of surgery in a series of cases with repair and no-repair, which did not show much difference in the overall outcome [11]. These

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research and other developments in the field, faded the repair techniques. It was noted that repair needs to be done early, and when not possible at all times caused inconvenience to the patient and to the surgeon.

## **ACL reconstruction**

### ***Intra-articular ACL reconstruction***

In 1917, Ernert W. Hey Grove reported the first ACL reconstruction using an iliotibial band [7], where he reported his series in 1920. Wills Campbell in 1935 first reported the use of patellar tendon, graft using bone tunnels [7].

Later many changes were done by Kenneth G Jones, Helmat Bruckner and Kurt Franke. These were all intra-articular reconstructions and lead to post-operative joint stiffness [7].

### ***Extra-articular ACL reconstruction***

In the 1970's non-anatomical ACL reconstruction became popular due to joint stiffness following intra-articular reconstructions. This led for the development of extra-articular ACL reconstruction. Macintosh procedure (D L Macintosh) using the fascia lata became popular during this time [12]. This eliminated the pivot shift which causes subluxation of tibia and instability. Later Macintosh introduced his second technique combining extra-articular and intra-articular techniques [13].

### ***Intra articular ACL reconstruction for the 2<sup>nd</sup> time***

In the 1980's again intra articular reconstructions became popular due to the work of John Insall who used the fascia lata [14]. Macintosh used central third of the patellar tendon which is still attached to its origin [15]. Clancy popularized the use of free patellar tendon graft [16]. Subsequently other tissues were used as free grafts, such as medial meniscus (which is no longer used) and hamstring graft. Popular grafts used are, free hamstring tendon, bone patellar tendon bone graft and allografts used through tunnels in tibia and femur.

During this period many synthetic grafts were tried such as braided silk, Gore-Tex, Carbon fiber modified scaffolds. None of these became popular and are not in use today. These were first introduced by L. Lange of Munich [15].

## ***Single and double bundle reconstruction***

Until the year 2000 almost all ACL reconstructions were done by the open method. In the early 2000s ACL reconstruction using bone-patellar tendon-bone and hamstring grafts were standard. During the same time ACL anatomy was well defined with regards to anteromedial and posterolateral bundles. Earlier with ACL reconstruction it was the anteromedial bundle which was replaced. Surgeons realized there were patients who still had some instability following a single bundle reconstruction. Therefore, double bundle reconstruction was introduced replacing both ACL bundles through tunnel in tibia and femur. At the same time partial replacement was also introduced to replace only the torn bundle.

In 2003, the double bundle reconstruction was described by Marcacci [17]. Surgery was popularized by Freddie H Fu in USA. Whether double bundle surgery is better than single bundles is debatable. Some has even demonstrated a 3rd bundle [18].

With the popularity of arthroscopy, ACL reconstruction has started to perform though the arthroscopic method.

Up to about 2011, most popular treatment for ACL injury has been arthroscopic reconstruction of ACL by a free hamstring graft or bone-patellar tendon-bone graft fixed though tibial and femoral tunnels [19].

## ***Repair of ACL ligament with suture reinforcement and 'internal splinting'***

During 2011 and 2012 Professor Garden Mackey reintroduced the repair of ACL ligament with suture reinforcement with a super strong polymer internal brace attached to tibia and femur through drill holes in tibia and femur [20]. With a super strong polymer intervening between bone and ACL ligament, will get reattached to the bone with regrowth of the ligament. The internal splint will stabilize the knee till the repair is complete. This procedure of 'internal splinting' is gaining momentum at present. Most important fact is that they need to be operated early and this is possible in tears detached from the femoral end.

At present, the debate of understanding the better surgical method; ACL reconstruction with single bundle/double bundle or repair with internal splinting will continue and it will take another decade to see the results.

At the same time when there is severe instability with grade III pivot shift, the intra articular reconstruction or repair may need to be combined with Macintosh type extra-articular reconstruction.

Chronologically the ACL surgery was direct repair, reconstruction, anatomical repair, intra-articular repair and extra-articular repair. At present, majority of the surgeons will do intra-articular anatomical reconstruction using hamstring tendon or bone-patellar with either single bundle or double bundle, via arthroscopy.

## Future

### **Direct repair enhancement** [21]

1. Internal Brace Ligament Augmentation (IBLA)  
Using of 2.5mm Polyethylene tap bridge between femoral tibia, with intensive micro fracturing of tunnels.
2. Dynamic Intraligamentary Stabilization (DIS)  
Use of a 1.8mm braided Polyethylene wire, pre waded between tibia and femur.

### **Biological enhanced repair** [22]

1. Bio- Scaffold
  - i. Use of hyaluronan
  - ii. Engineered Collagen
2. Use of platelets and platelet rich plasma (PRP)
3. Use of Mesenchymal Stem Cells (MSC)

## Conclusion

Anterior cruciate ligament has come a long way from no treatment to intra-articular repair, to extra-articular reconstruction to intra-articular reconstruction with single bundle to double bundle, body to intra-articular repair and combined intra-articular and extra-articular surgery. Most importantly the outcome of the surgery and return to play of athletes will improve with further advancement of the surgical techniques.

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