Journal of Interdisciplinary Medicine

Volume 2 // Supplement 3 // May 2017

International Knee Arthroscopy Course 2017

3rd Edition

Tîrgu Mureș, 17–20 May 2017

FOCUS ISSUE

Orthopedics // Arthroscopic Surgery

Acknowledgement

This supplement was supported by an unrestricted grant
by the Cardiomed Reserch Center
(for editorial support only)

Journal of Interdisciplinary Medicine

Volume 2 // Supplement 3 // May 2017

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Journal of Interdisciplinary Medicine

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REVIEW

ORTHOPEDICS // ARTHROSCOPIC SURGERY

ACL Primary Repair with Bone Marrow Stimulation and Growth Factors. A Review of Literature

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ARTICLE HISTORY

Received: April 28, 2017
Accepted: May 12, 2017

ABSTRACT

Anterior cruciate ligament (ACL) ruptures represent a common pathology, especially in young and active patients. Spontaneous repair, although reported in some studies, is altered by local conditions, thus emerges the need to perform reconstruction of the ACL. It is reported that 3,430 primary reconstructions and around 267 revisions are performed yearly in Sweden. Some reconstructions result in biological failure, which represents the inability of the graft to incorporate and remodel in order to perform its role as a knee stabilizer. Orthobiology, a new concept that includes growths factors, stem cells, and different scaffolds, could represent a solution to a better outcome of this procedure. This manuscript is a review of different therapeutic strategies used for enabling ACL regeneration, including in vitro ACL-bio-enhanced repair that is currently being developed. Substantial progress is to be expected in the area of ACL surgery.

Keywords: ACL reconstruction, growth factors, stem cells, orthobiology

INTRODUCTION

The anterior cruciate ligament (ACL) represents one of the most important knee stabilizers and one of the most frequently wounded ligaments in young and active persons. It is well known that the ACL has two bundles, the anteromedial one and the posterolateral one.[1] These two bundles work together to stabilize the knee joint both in flexion and extension. The ACL is the most important stabilizer of the anterior translation of the tibia, but it also helps with rotation and valgus stress. It is an intra-articular ligament with its own synovial membrane; hence, some consider the ligament as extraarticular. When an injury occurs and the ACL is torn, the synovial membrane also ruptures, and the ligament is exposed to synovial fluid, proteolytic enzymes, and hemorrhagic breakdown products.[1,2] These are the main reasons why spontaneous healing is not possible. Although some studies mention good functional results after conservative treatment, the main accepted treatment nowadays is the surgical reconstruction of

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the ACL.[3,4] There are many tissue sources that can be utilized to reconstruct the ligament, both auto- and allografts. When talking about autografts, hamstring is reported to be used in about 98% of cases, but patellar tendon and quad tendon can also be used.[5] Allograft options include synthetic materials or tissue from tissue banks. The Swedish ACL Register reports an annual rate of 3,430 primary reconstructions of ACL for 2014 with an increasing number each year and a rate of 267 revisions per year.[5] More than half of the patients are men and the average age is 28 years.

There are certain known problems that lead to failure of a reconstruction, thus making it a complication both for the surgeon and the patient. The main problems regarding failure are technical errors such as tunnel location, graft impingement, inadequate graft dimensions, or graft fixation.[6] The tunnel location is the primary source of bad outcome, but surgeons strive to be as anatomic as possible, and the results have been improved. Other causes that lead to failure are traumatic injuries and biological failure. The latter is regarded as a lack of ligamentization one year post-implantation, and one has to deal with a lax and atonic graft, and more important, a non-functional reconstruction. Biopsies of the graft reveal marked necrosis, few viable cells, lack of vascularity, and disintegration of collagen.[7]

The ligamentization process includes several steps such as graft necrosis, which happens mainly in the central part of the graft, lasts for about three to four weeks, and is an avascular necrosis. The next step is the revascularization, followed by cell repopulation and proliferation. The graft reaches full perfusion around six to eight weeks, and the cell proliferation occurs mainly from the infrapatellar fat pad and the posterior synovial tissues. The final step is collagen remodeling, finalized around 12 weeks postoperatively. For the collagen production to take place, it needs the previous steps to be completed and to have good mechanical forces applied to it.[8]

The biological failure of a graft is intended to be overcome by regenerative means such as growth factors, stem cells, and even several scaffolds.

GROWTH FACTORS

Growth factors (GF) can be administered either directly by local delivery, by inserting the cells that produce them at the site of interest, or through gene-modifying therapies. There are a variety of GF, including insulin-like growth factor (IGF), transforming growth factor (TGF-ß), platelet-derived growth factor (PDGF), vascular endothelial growth factor (VEGF), epidermal growth factor (EGF), and fibroblast growth factor (FGF) that have been used to improve ligamentous healing capabilities. Growth factors exhibit the ability to stimulate the anabolism of the cells in the ligament, thus improving cell proliferation and extracellular matrix (ECM) deposition, and can also enhance the differentiation of mesenchymal stem cells (MSCs) into fibroblasts.[9,10]

PLATELET-RICH PLASMA

Platelet-rich plasma (PRP) is gained through centrifugation of whole blood, leading to plasma separation containing thrombocytes, serum proteins including fibrin, and several growth factors (PDGF, VEGF, TGF-β, and IGF). PRP has a minimum thrombocyte concentration of 1,000,000 cells per microliter and a 3- to 5-times higher GF and cytokine concentration.[11]

In a review by Andriolo *et al.* they found 15 studies that used PRP with ACL grafts. Most studies had used hamstring tendons for ACL reconstruction, while a bone-tendon-bone (BTB) was used in 4 studies and an allograft in one study. PRP was utilized in the clear majority of the studies to promote graft bone integration and was applied directly on the surface of the tendons used for reconstruction. PRP was activated in 14 studies before intraarticular administration.[12]

Considering the graft maturation process, four studies found results in favor of PRP administration, while two reported no differences. When documenting the graft's integration into the bony tunnels, seven authors found no better outcome in the PRP group. Bony tunnel widening was assessed in three reports, and none revealed a better prognosis with PRP injections.[13–15] The most important feature of this series of clinical studies was the fact that PRP treatment is a safe procedure with no side effects reported in any study. No infections and no other complication were noted, and two studies even showed improved local healing when administered to the local harvest site of the BTB.[16,17] The results of this review provided questionable results regarding ACL augmentation and PRP usage. Nevertheless, PRP is a secure procedure providing benefits in the healing mechanism after ACL surgery.

STEM CELLS

Mesenchymal stem cells are found in the majority of tissues in the body (bone marrow, fat, muscles, and placenta). For the purpose of cellular therapies, MSCs recruited from the bone marrow and fat tissue are the most frequently used. MSCs have the ability of high expansion and self-renewal, and the potential of multi-differentiation.[18]

Bone marrow-derived mesenchymal stem cells (BM-MSCs) have been researched widely, but adipose-derived stromal cells (ASC) are accessible cells that can replace BM-MSCs. The abundance of tissue and the simplified harvesting process have made the adipose tissue a new source for providing cells for regenerative medicine.[19] The minimal criteria that define the MSCs set by the International Society for Cellular Therapy include the presence of CD105, CD73, and CD90 surface marker, the lack of CD45, CD34, CD14, CD31, and HLA-DR markers, their capacity to stick to plastic and to differentiate into osteogenic, chondrogenic, and adipogenic lineage.[20]

Kanaya *et al.* studied from a biomechanical and histological point of view if MSCs can improve the healing of a partial ACL rupture in a rat model. They reported improved outcomes both from biomechanical and histological point of view.[21]

Silva *et al.* investigated the use of non-cultivated BM-MSCs in ACL reconstruction in humans. Unfortunately, no characterization of the aspirate, viability, or numeration was provided. MRI did not detect any differences between BM-MSCs and the control group.[22]

Both Soon *et al.* and Lim *et al.* showed, in a rabbit model, that MSCs enhance the graft osteointegration both for autograft and allograft. In both studies the MSCs improved ACL reconstructions providing significantly better results than the control groups.[23,24]

Cheng *et al.* found better results when researching stem cells derived from the ACL itself in comparison to bone marrow-derived MSCs in ECM production and proliferation rate.[25]

SCAFFOLDS

Various biomaterials have been presented as potential scaffolds for the ACL. A scaffold is a biological match, and its mechanical features resemble those of the native ACL. The structure of a scaffold has to be biodegradable in order to enable tissue ingrowth and in time to reestablish the structure of a native ACL.[26] The scaffold must be flexible in the low-tension stresses of everyday motions, but very strong in the larger range strain, in order to ensure knee stability.

Dunn *et al.* and Bellincampi *et al.* developed scaffolds made of collagen fibrils and reported that ACL fibroblasts adhere to the scaffold both in vivo and in vitro, but unfortunately at six weeks the combination was disintegrated.[27,28]

Murray *et al.* showed that a collagen-glycosaminoglycan compound scaffold maintained cell growth and proved that the human ACL cells can migrate weeks after the rupture into the scaffold.[29] Panas-Perez *et al.* developed a collagen-silk complex and concluded that a roughly 50% composition of silk assures the minimal requirements of a functional ACL in vivo.[30]

Altman and Kaplan managed to twist fiber scaffolds to match the strength of the native human ACL.[31] Fan *et al.* showed that a silk ligament scaffold in conjunction with seeded MSCs support ligament repair, and although degradation was present at twenty-four weeks after implantation in a pig model, it still maintained sufficient tensile load.[32] Electrospinning has been utilized to develop scaffolds for ligament tissue engineering.[33] This method may be used to create very strong fibers ranging from nanometers to microns in size, allowing a more exact adaptation of the mechanical features of the construct.

FUTURE DEVELOPMENTS

The era of orthobiology is just starting to develop. New biomaterials and novel techniques for the improvement of cell and scaffold management will be developed. This will involve developing new therapies, based on regenerative medicine. In regards to cellular therapies, the mechanisms involved in such procedures are yet to be fully discovered.

CONFLICT OF INTEREST

Nothing to declare.

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REVIEW

ORTHOPEDICS // ARTHROSCOPIC SURGERY

Anterolateral Ligament (ALL) — Myth or Reality?

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ARTICLE HISTORY

Received: April 25, 2017
Accepted: May 13, 2017

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ABSTRACT

Although the anterolateral ligament (ALL) was described a long time ago, recent research shows a lot of interest regarding this structure. There is a high variability concerning its anatomy, especially its capsular/extracapsular situation and insertion sites. There is also some controversy about its ligamentous structure. It seems that it has a biomechanical role in restricting anterior tibial translation and internal rotation. The ALL complex seems to have a clinical significance, and a relationship with the pivot shift has been described. Although there are promising results recently, the surgical techniques of ALL reconstruction, in addition to anterior cruciate ligament reconstruction, have to be further investigated. A precise indication algorithm and patient selection criteria need to be established.

Keywords: anterolateral ligament (ALL), anterolateral complex, anterior cruciate ligament (ACL), ACL reconstruction

INTRODUCTION

The anterolateral ligament (ALL) has been recently brought into attention after the paper of Claes received considerable public and media attention.[1] A large debate regarding the ligament’s anatomical landmarks, histology, functional role, best method of surgical reconstruction, and even its actual existence was generated. Although a final verdict was not yet achieved, this research enhanced our knowledge to the benefit of our patients.

However, this structure is far from new. Segond first described it in 1879, as a reinforcement of the lateral joint capsule by fibers of the iliotibial band, and the avulsion fracture of the tibial plateau was named the “Segond fracture”.[2] Then, in 1948, Last named it “short lateral ligament”.[3] In 1976, Jack Hughston[4] described the anterolateral structures and the middle third of the lateral capsular ligament, and in 1982 Werner Muller[5] identified it as the lateral femorotibial ligamentous attachment. In 1986, Terry showed that there is a “capsulo-osseous layer” of the iliotibial band, while LaPrade described it as a “mid-third lateral capsular ligament” and included it in the so-called “anterolateral complex”.[6,7] Finally, Vieira named this structure as we know it today – “anterolateral ligament”.[8]

Anterior cruciate ligament (ACL) surgical techniques have evolved during the years, but residual pivot shift remains a concerning issue. Therefore, more interest was addressed to the anterolateral peripheral structures. In the last years there was a large amount of research regarding the ALL; however, no definitive consensus regarding this structure has been achieved.[1,9–14]

VARIABILITY

Due the conflicting results that were published, some confusion is still present. The ALL seems to have a certain variability that occurs in at 33–97% of the human population.[1,4,15,16] Whether the ALL is absent from a specimen or has simply been obliterated or overlooked can be due to the multiple dissection techniques.[17] The impact of an ALL absence, even if only unilateral, needs to be investigated in clinical and imaging studies to finally clarify its importance.[18]

CAPSULAR VERSUS EXTRACAPSULAR

There are studies that identify the ALL as a capsular structure with attachments to the lateral meniscus.[1,19] In contrast, other studies support the idea that it is an extra-capsular structure originating from the iliotibial tract, with no relation to the meniscus.[10]

The iliotibial tract consists of an 8 cm wide collagen structure, which originates from the iliac crest and iliac spine. At knee level, fibers from the iliotibial tract reach the patella (retinaculum), while others reach the septum intermusculare. The distal insertion is on Gerdy’s tubercle. There are three layers: superficial, deep, and capsulo-osseous.[12] The deep layer consists of fibers that reach the intermuscular septum at 6 cm proximal to the lateral epicondyle and anchor the iliotibial tract on the femur (Kaplan fibers).[20]

The capsulo-osseous layer consists of the fibers that originate cranially and posterior of the lateral epicondyle and insert on the tibia, posterior from the Gerdy’s tubercle. These fibers correspond to the so-called ALL.[21]

Regarding the relationship to the lateral collateral ligament (LCL), the ALL is described as being superficial to the LCL.[22] Many ALL reconstruction techniques have used a graft passing deep to the LCL, which could explain the over-tightening and the sub-optimal results seen with these methods.[23] Other researchers consider that the ALL and the deep capsulo-osseous fibers of the iliotibial tract are in fact one and the same structure.[21]

The Anterolateral Ligament Expert Group concluded in a recent paper that there is a consensus that the ALL is a triangular, anterolateral structure found deep to the iliotibial band, admitting that there is a lot of debate concerning the exact specifications of the ligament.[24]

LENGTH, THICKNESS, WIDTH

There is also a variability regarding the length of this structure, from 37 to 59 mm.[10,19] The width seems to be less than 10 mm.[1,16,22,23] The thickness also presents great variability – from 0.87 mm to 2–3 mm.[15,23] This variability depends on the dissection technique. The structures are difficult to be separated.[23]

INSERTION

There is some controversy regarding the femoral and tibial insertions of the ALL. Claes and Bellemans (2013) found that the ALL originates at the lateral epicondyle of the femur, near the origin of the LCL, crosses the joint, attaches to the lateral meniscus, and inserts at the anterolateral aspect of the proximal tibia between the Gerdy’s tubercle and the fibular head.[1] Following this article, many authors performed anatomical studies, trying to define exactly the macro- and microscopic landmarks of this structure.

Vincent *et al.* (2012) reported the origin to be the lateral femoral condyle.[15] Other authors reported slightly different insertion points. The different results can be related to the anatomical differences of the specimens, but also on the preparation methods. However, the majority of researchers conclude that the femoral insertion point lies posterior from the lateral epicondyle, and the tibial insertion is located just posterior to the mid-point of Gerdy’s tubercle and fibular head.[9,14,23]

The ongoing controversy that surrounds this structure reveals the difficulty of understanding the peripheral anatomy. It is not always possible to clearly define these structures, that is why one can discuss about complexes (posterolateral, anterolateral, posteromedial, anteromedial) rather than well-defined single units.[5,21,26]

Although most studies show that the anatomy and topography of the ALL seems to be highly variable, they also underline that it is consistent within certain limits.[18]

Thus, it is a reality that this structure exists. But is it truly a ligament or, similarly to the glenohumeral ligaments of the shoulder, just a thickening of the capsule that is part of an anterolateral complex?[13]

HISTOLOGY

Histological analysis from certain studies revealed characteristics of ligamentous tissue, and immunohistochemistry identified a network of peripheral nerves, suggesting a proprioceptive function of the ALL.[26,27] Guenther *et al.* stated that, histologically, the collagenous structure of the ALL is significantly different from the LCL, thus questioning the ligamentous origin of the ALL. Parts of the anterolateral capsule are organized into individual bundles, most likely a combination of multiple thickenings of the capsule, and not a homogenous ligamentous entity such as the ACL or LCL.[22,28] Thus, although there are some similarities between the ALL's structure and ligaments, it seems that the ALL does not fulfill the necessary criteria to be called a ligament.

FUNCTION

Internal rotational stability of the tibia is mainly restricted by the ACL, but other anatomical structures (the anterolateral complex, or the posterior horn of the meniscus) also act as secondary stabilizers.[29,30]

Regarding the function of the ALL, Terry *et al.* suggested that the anterolateral structures may play a role as a rotational knee stabilizer.[31] The ALL fibers seem to stabilize the internal rotation of the knee and the anterior translation of the lateral tibia plateau, extra-articular, together with the ACL, which is the most important intra-articular contributor to rotatory knee stability.[1,32–35]

Drews *et al.* concluded that the ALL is supporting the ACL against internal tibial loads to a minor degree, and that there is no apparent relationship between the ALL and the pivot shift. Therefore, ALL reconstruction cannot be recommended at the moment without further biomechanical investigations.[36] From a biomechanical point of view, internal rotation of the knee is better controlled by a lateral extra-articular structure compared to the centrally located ACL because of a longer lever arm.[37,38]

Cadaveric studies showed that starting with 30 degrees of flexion, the deep capsulo-osseous fibers of the iliotibial tract play an important role regarding the rotational stability of the knee, while the ALL is just of secondary importance.[12] Other studies showed that sectioning of the ALL in addition to the ACL, in cadaver specimens, enhanced the pivot shift significantly.[1] Monaco *et al.* suggested that the anterolateral structures play even a larger role than the posterolateral bundle of the ACL in controlling rotational stability.[39]

Despite the extensive research on the ALL, there is no consensus regarding its structure and biomechanical function. It seems that the ALL is a stabilizer against internal tibial rotation, particularly at flexion angles greater 30 degrees, and rupture of this structure/complex may be involved in the pathogenesis of a high-grade pivot shift.[40]

The consensus of the ALL Expert Group stated that the mean load to failure is around 180 N, the mean stiffness is 31 N/mm, and the ALL acts as a restraint for the internal rotation of the tibia and affects the pivot shift in the ACL-deficient knee.[24]

THE SEGOND FRACTURE

Segond described the avulsion fracture of the tibial plateau as the “Segond fracture” back in 1879.[2] This is considered a pathognomonic radiographic feature for an ACL injury.[41] The anatomic structure responsible for the Segond fracture is not yet defined, although the suggestions include the anterolateral capsule, the anterior oblique band of the fibular collateral ligament, the iliotibial band, the short head of the biceps femoris, and the ALL.[10,41,42]

There is some evidence that the load of the ALL and anterolateral complex increases during ACL injury, and these structures might be responsible for the Segond fracture. Therefore, while evaluating the injured knee, one should closely evaluate the anterolateral structures as well.[1,25,43,44]

CLINICAL AND SURGICAL SIGNIFICANCE

Before modern ACL reconstruction techniques were developed, isolated lateral extra-articular procedures were used as the standard surgical techniques in patients with ACL insufficiency. These procedures were non-anatomic, reproduced the biomechanics poorly, and resulted in residual instability and over-constraint of the lateral compartment (with secondary osteoarthritis), thus being abandoned.[40,45]

Isolated ACL ruptures do not produce an increased pivot shift, but additional disruption of the anterolateral structures generates a high-grade pivot shift.[39,46] In the last years, several anterolateral stabilizing techniques were described in order to address this issue.

The exact indication remains uncertain, because there is no study that fully proved that anatomic ALL reconstruction, in addition to the ACL reconstruction, adds real benefits. It seems that there is only a theoretical advantage related to the ALL reconstruction.[47]

Although there are a large number of studies and many debates regarding this topic, the majority of experts accept some potential indications for ALL reconstruction, based on the severity of injury: patients with high-grade pivot shifts, selected revision cases, and some high-level pivoting sports. More studies are needed to establish adequate treatment algorithms based on the individual anatomy of the patient.[48–51]

CONCLUSION

In our opinion, the key points in understanding the ALL structure include defining its anatomical attachment sites on the femur, tibia, and lateral meniscus and its precise role in knee biomechanics; evaluation of its histological composition, as well as the consequences of its insufficiency. Also, it is important to make a precise diagnosis (clinical, radiological – MRI, US), to study the natural healing potential of the ALL, the exact operative indications, and the best surgical reconstruction technique.

CONFLICT OF INTEREST

Nothing to declare.

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Will Total Knee Replacement Ever Provide Normal Knee Function?

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ARTICLE HISTORY

Received: April 26, 2017
Accepted: May 13, 2017

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ABSTRACT

Knee osteoarthritis or gonarthrosis is considered the most common joint disease, affecting more than 70% of subjects aged over 65 years. Its occurrence is increasing with age and is more problematic with the current rise in the incidence of obesity. In severe and advanced cases, total knee arthroplasty is recommended as a gold standard therapy for pain relief, restoration of normal knee function, and quality of life improvement. There are numerous controversies whether total knee arthroplasty is able to reach and provide end-point outcomes and restore previous function of the knee joint. Studies suggest that the surgeons' experience, type of prosthesis used, associated pathology, underlying pathologies, risk factors, continuous passive movement, and patient expectations about the surgery may influence the outcomes to a great extent. "Normal knee function" is a statement that is hardly defined in the current literature, as authors usually refer to subjective results when analyzing outcomes. Objective results may be more straightforward, but they do not always symbolize the actual state that the patient is reporting or the actual quality of life. Our objective was to analyze and present summaries of the current literature regarding normal knee function restoration after total knee replacement surgery. Our literature review results confirm the hypothesis that subjective and objective results are difficult to interpret and unravel. Complex future trials may bring supplementary and clearer conclusions regarding knee function and kinematics, clinical improvement, patient satisfaction, and quality of life.

Keywords: knee replacement, total knee arthroplasty, outcomes

INTRODUCTION

Osteoarthritis (OA) of the knee or gonarthrosis is the most common joint disease, its occurrence increasing with age. Its prevalence reaches 30% between 45–65 years and about 70% in subjects aged over 65 years. Disease distribution is identical for both genders under the age of 55, but between 55–75 years, women seem to have a higher incidence.[1] Gonarthrosis is the consequence of a functional imbalance between the strength of the articular structures and the stresses, friction, and traumas exerted on them. When demands become amplified and go beyond the physiological threshold or normal stresses are exerted on a low-strength cartilage, the conditions for alterations in cartilage are created.[2] Together with underlying biomechanical factors that may predispose subjects to knee OA, obesity, previous knee injuries, and intensive physical activities are considered key risk factors for the development and advancement of the disease and the necessity for total knee replacement.[3–5] Total knee arthroplasty (TKA) is now considered the gold standard therapy in treating end-stage knee osteoarthritis, with a nearly 90% patient satisfaction rate reported in recent studies.[6–12] Even with the high patient satisfaction rate reports, some studies also suggest that TKA is not achieving its primary goal of pain relief and improvement of joint function.[13–15] The successfulness and outcome of a TKA mainly depends on the senior surgeon and his interaction with instruments, the operating team, and patient, his skill, learning curve, enthusiasm, and hospital facilities that are available.[16] The surgeon's actions are considered to have the prime effect on outcomes: postoperative instability, malalignment, poor range of motion, sepsis, and other failure outcomes. Besides the surgeon's experience and managerial skills, rehabilitation and physiotherapy after the intervention is also essential in order to achieve the functional and clinical outcomes that are expected.[17] Our review sought to highlight the outcomes reported in the literature after total knee replacement and to answer the question whether TKA restores the previous functionality of the affected joint.

NORMAL CARTILAGE DESCRIPTION AND PATHOGENESIS OF KNEE OSTEOARTHRITIS

The parts covered by cartilage in the knee joint are the femoral condyles, the tibial plateau, and the posterior surface of the patella. Thus, the articular movements are achieved by sliding between these three cartilage surfaces.[18] The normal articular cartilage achieves two essential functions for locomotion: the transmission of mechanical forces to the bone extremitie,s and a smooth, perfectly congruent, self-lubricated surface. Usually, the cartilage is exposed to a continuous internal remodeling process, considered to be the result of the activity of chondrocytes and synovial cells.[19] Cartilage cells show a low rate of division due to reduced DNA synthesis.[19] Due to the hypocellularity of the articular cartilage, its mechanical and biochemical characteristics are dependent on the composition of extracellular matrix.[19] Due to the increased concentration of proteoglycans, normal cartilage is poorly water-permeable. When a compressive force is applied, although the pressure in the cartilage increases immediately, it deforms slowly and reversibly, as the water surrounds the entire joint surface as a smooth film. When the force is removed, the layer of fluid on the surface of the cartilage is absorbed by proteoglycans, which have a high density of negative charges. The capacity of proteoglycans to retain water and to increase in volume is limited by the tensioning collagen network. Hydrated proteoglycans are compressed into the meshes of the collagen network, creating considerable tissue pressure even in the absence of compressive forces.1 The etiology of knee OA is usually described as intra-articular and extra-articular. Intra-articular causes produce a functional overload due to defective mechanical conditions such as traumas, meniscus and ligament lesions, quadriceps muscle atrophy, or König's disease. On the other hand, extra-articular factors include deviations in the frontal (genu valgum or varus) or sagittal planes (genu flexum). The existence of anatomical malformations favoring articular overload (genu varum, genu valgum, lateral instability of the spine) are recognized as "pre-arthritic malformations" because they favor and lead to OA over time.1 In addition to these causes, a number of factors contributing to overweight, prolonged kneeling professions, and sports (football, rugby, skiing) are also encountered in the etiology of the disease. OA may reach only a part or the entire knee joint, thus distinguishing the following locations according to knee anatomy:[20]

- internal tibio-femoral OA that concerns the inner compartment of the knee joint;
- external tibio-femoral OA that concerns the outer knee compartment;
- femoral-patellar OA involving the patello-femoral compartment of the knee;
- global OA of the knee joint.

SHORT DESCRIPTION OF THE CONVENTIONAL TKA SURGICAL TECHNIQUE[21]

There are several techniques described in orthopedics regarding TKA, which is performed under aseptic conditions, under spinal or general anesthesia, with the patient in dorsal decubitus and the knee to be operated in a 90° flexion position. A tourniquet can be applied around the thigh to help surgical exposure and limit the blood loss, but this practice should be avoided in patients with a history of deep vein thrombosis.

The knee joint is approached anteriorly by a para-patellar medial incision; the osteophytes and the intra-articular soft tissue are afterwards removed. The bony excisions in the distal femur are perpendicular to the mechanical shaft using an intramedullary alignment system. In the proximal tibia, bone excisions are also perpendicular to the mechanical shaft, but both intramedullary or extramedullary alignment systems can be used. Restoring mechanical alignment is important to allow optimal distribution of the knee load and to prevent eccentric loading. Enough bone should be removed so that the prosthesis will re-create the level of the joint line. This allows the ligaments around the knee to be perfectly balanced and thus prevent possible alterations of the height of patella, which may have a damaging effect on femoral-patellar biomechanics.

Due to the preoperative deformation, some ligaments around the knee are contracted. These will be strained gradually to balance the soft tissues around the knee and allow optimal kinetic articulation. After the intercondylar space is prepared, the mobility of the new articulation (flexion, extension) with the test components is controlled, and the bone surfaces are washed. If the patellar-femoral joint is significantly affected, the patella surface may be restored with a polyethylene component. The initial width of the patella should be restored.

Once the final components have been selected, they are fixed with polymethyl methacrylate cement. If non-cemented prostheses are used, they are set by the press-fit technique, and the bone growth around the prosthesis will ensure the fixation in the long term. The tourniquet should be removed before closing, and the knee joint is usually drained and fixed in full extension. At the end of the intervention, the pulse at the level of the dorsalis pedis artery is tested.

OUTCOMES AFTER TOTAL KNEE ARTHROPLASTY – LITERATURE REVIEW

With the implementation of modern prosthetics, the survival rates following TKA have increased radically to a 90% rate at 15 years after the surgery.[22]

I. Patient satisfaction

With increased survival rates, the patients' satisfaction, post-surgery joint performance and functionality have become an obligatory topic. Meeting patient expectations is of the highest significance in achieving patient fulfilment after primary TKA.[9,12,23] It was demonstrated that patient expectations regarding surgery have a significant effect on the satisfaction rate after surgery, even if functionality was not completely restored.[13] Robertsson *et al.* studied whether Swedish patients operated by knee arthroplasty are satisfied with the procedure or not.[14] They ran a questionnaire on 27,372 subjects who underwent knee arthroplasty between 1981 and 1995 in the Swedish Knee Arthroplasty Register. Their follow-up range was between 2 and 17 years, and 92% of the individuals were satisfied with the outcomes of the procedure. However, a higher rate of satisfaction was reported in those who underwent TKA compared to unilateral compartment arthroplasty. In a similar observational study, Anderson *et al.* found that 88.8% of subjects were satisfied with the surgery, and 91% felt that they made the right decision when opting for total replacement.[24] An important detail was that patients with higher satisfaction rates were also scoring better in the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) evaluation ($p < 0.05$).

II. Subjective outcomes

In 108 patients who underwent TKA with an average of 4.9 years of follow-up, the WOMAC subjective score and patient satisfaction were studied.[25] WOMAC was once again correlated with the self-reported satisfaction level. Seventy-three patients (68%) were "very satisfied" with the surgery. In a study from 2009, Bourne *et al.* assessed patient satisfaction on subjects who underwent TKA.[26] From 1,703 patients, 1375 (81%) were satisfied with the overall procedure results. WOMAC is the most common tool used to evaluate subjective outcomes after treating osteoarthritis and includes questions regarding three main subscales considered as end-points: pain, stiffness, and physical function.[27,28] The score usually ranges from 100 to 0 (from worse to best), but some authors reverse the score in their reports from 0 to 100, a 100 score showing the best outcome possible. In Bourne's study, the reversed WOMAC score improved significantly to 81.9 ± 16.6 with an average overall change of 39.5 ± 19.8 at the one-year follow-up.26 In their report, the pain subscale had the highest change compared to the preoperative state (86.2 ± 16.3, with a change of 42.9 ± 20.6 in 12 months).

III. Surgical technique and prosthesis type influence the desired outcomes

A common discussed topic in the orthopedics community is whether to use posterior stabilized arthroplasty or retain the posterior cruciate ligament (PCL) during surgery. It is a topic of debate, as several authors and systematic reviews provided evidence that sacrificing the PCL might lead to better functional outcomes and a reduced range of motion limitation.[29,30] Other authors concluded in 2008, using a sample of 100 patients, that the two techniques had shown no superiority to each other regarding pain, quality of life, and knee function two years post-surgery.[31] Seon *et al.* demonstrated that posterior stabilized TKA is superior in terms of weight-bearing flexion, but with no superiority observed in the clinical outcomes.[32] It is additionally considered that the type of prosthesis is influencing the results after TKA. In a meta-analysis comprising 130 studies, Callahan *et al.* analyzed reported outcomes after TKA with the following techniques: PCL-sacrificing TKA, PCL-retaining TKA, and PCL-substituting TKA.[33] The mean range of motion was 99 degrees following a PCL-sacrificing TKA, 107 degrees after PCL-retaining knee arthroplasty, and 103 after PC-substituting TKA. They also concluded that underlying knee pathology and prosthesis type can be considered as predictors for outcomes following TKA. After analyzing data regarding postoperative flexion range of motion following 313 PCL sparing TKAs, Parsley *et al.* affirmed that subjects who had limited flexion preoperatively showed an increase in flexion after surgery.[34] In comparison, individuals with above 105 degrees of flexion before surgery showed a decline in flexion after the surgery.

IV. Associated risk factors and underlying disease

Associated disorders, underlying disease type or risk factors may influence the final outcome after knee replacement. Patients who underwent TKA with underlying rheumatoid arthritis, septic arthritis, or avascular necrosis had reduced flexion range of motion postoperatively (100°) compared to subjects with OA, trauma, or gout (120°) as a primary diagnosis.[35] Studying the same topic, Harvey *et al.* concluded that patients who had OA as a primary diagnosis lost 2° of flexion after TKA, and patients who had rheumatoid arthritis as underlying disease gained 5° of flexion at a minimum 12 months follow-up.[36]

V. Continuous passive motion – yes or no?

Usage of continuous passive motion (CPM) is a frequent topic addressed in the rehabilitation process after TKA for obtaining better clinical and subjective results. One of the fundamental meta-analyses that addressed this topic was published in 2004 by Brosseau *et al.*, which concluded that CPM, in addition to physiotherapy, has statistically significant superior effects when analyzing active knee flexion and decreased hospitalization time compared to physiotherapy alone.[37] However, CPM usage was not correlated with better passive knee flexion and passive or active knee extension. In a review elaborated for French clinical practice guidelines, CPM was found to provide beneficial effects regarding pain, swelling, and knee kinematics, together with a shorter recovery time post-surgery.[38] However, a clear statement regarding long-term outcomes could not be elaborated due to short follow-up times in studies reporting CPM as rehabilitation procedure. Pope *et al.* reported beneficial postoperative outcomes and reduced joint manipulation, but only for a short time.[39] At one week after TKA, there was a statistically significant increase in the range of flexion and total range of movement in the group that used CPM. At one year, however, they found no significant differences in mean flexion, range of motion, or functional results between the groups.

CONCLUSIONS

The review of the literature has many contradictions and controversies between the authors' opinions and the obtained results. Higher-evidence trials may bring further clear statements regarding knee function, clinical improvement, patient satisfaction, and quality of life. Will TKA ever be able to provide normal knee function? If we address normality as a patient subjective outcome and satisfaction after the surgery, we can state that TKA provides sufficient beneficial effects to restore normal knee function. If objective outcomes are assessed, the conclusion whether a knee is functioning normally is hard to be established among the literature's disagreements.

CONFLICT OF INTEREST

Nothing to declare.

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REVIEW

ORTHOPEDICS // ARTHROSCOPIC SURGERY

Prevention of Primary ACL Injuries: A Novel, Innovative Approach

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ARTICLE HISTORY

Received: April 24, 2017
Accepted: May 13, 2017

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ABSTRACT

Anterior cruciate ligament (ACL) injuries are increasing amongst professional and recreational athletes, and creating prevention programs to reduce the occurrence of ACL damages is becoming a necessity. To prevent an ACL tear, it is necessary to comprehend the mechanisms and the risk factors of injury. Biomechanical and clinical studies try to understand these complex mechanisms in order to identify factors that can be improved and to develop training programs to prevent at least non-contact ACL injuries. There are several promising programs, but there are still many questions to answer. This paper analyzes the risk factors for ACL injuries and some aspects of the modern programs developed to decrease the rate of ACL tears.

Keywords: anterior cruciate ligament injury, knee, instability, prevention, risk factors

INTRODUCTION

Anterior cruciate ligament (ACL) injuries are commonly encountered in professional and recreational athletes. There are many scientific projects aimed towards ACL injury treatment plans, but there is still a significant percentage of reconstruction failures with important long- term disabilities, reduced knee function, and significantly increased risk of developing knee osteoarthritis.[1] Analyzing the mechanism of ACL rupture, McNair and Boden found in 1990 and 2000 respectively, that around seventy percent of ACL tears take place as a non-contact injury and therefore might be, in theory, preventable.[2,3] Creating prevention programs to decrease the incidence of ACL injuries is a logical step. In 1996 Caraffa *et al.* published for the first time a prospective study on the prophylaxis of ACL tears in soccer and showed that proprioceptive workout can meaningfully decrease the rate of ACL in these athletes.[4] Even if initially the notion of ACL tear prevention was debatable, in recent years important research has been undertaken to prove that prevention programs can reduce the incidence of ACL injuries. An analysis of 7 studies on ACL injury prevention programs, carried out between 1999 and 2008, found that participation in a prevention program decreased the risk of non-contact ACL tear by 71% on average.[5] Prevention programs can also diminish the rates of other knee and ankle injuries.[6] To be effective, these programs must be followed throughout the season; this requires a combined effort from the athletes and their coaches.

The present paper aims to present an analysis of the risk factors involved in ACL injuries and the results of the prevention programs.

RISK FACTORS

There are several studies showing an increased risk of up to six times for females to have an ACL tear.[7,8] This leads to the assumption that there are several gender-related factors that influence the risk of having an ACL tear.

Analyzing the factors that can influence the risk of ACL damage, we can describe non-modifiable and modifiable biological factors, and environmental factors. Non-modifiable factors cannot be influenced, therefore cannot be decreased by any prevention program. In 2007 Hewett *et al.* published a systematic review of studies analyzing the association between ACL injury and menstrual cycle.[9] Certain studies found a significant risk of ACL tear in the pre-ovulatory phase and a lower injury rate in females taking contraceptive pills, but no definite indication that hormonal changes are linked with ACL injury or the use of oral contraception. Ligamentous laxity is considered to be a risk factor for ligament injuries, as it has been demonstrated by published studies.[3,10] The increased posterior tibial plateau slope seems to be correlated with a significant risk for ACL tear due to the increased peak of ACL strain.[11–13] Notch width seems to be an important anatomic factor correlated with the risk of ACL tear, given that a minor notch invades the ACL.[14] Souryal *et al.* proposed the notch-width index and showed that notch-width narrowing was significantly correlated with non-contact ACL injuries.[15] Chaudhari *et al.* showed that ACL injured subjects had significantly lower ACL volumes compared with those measured in controls.[16] This can be correlated with the findings of Dienst *et al.*: a lower notch-width index is linked to a smaller ACL.[17] Another biological factor that correlates with ACL injury risk seems to be the maturation of the skeleton, muscles, and neurological function. There is no difference between pre-adolescent gender characteristics, but following maturation, males undergo an increase in strength and coordination, allowing an increased neuromuscular control with differences in jumping and landing.[18,19]

The modifiable factors involved in ACL injury risk are represented by neuromuscular imbalances.[20] Hewett *et al.* named the neuromuscular disproportion that causes valgus collapse as the ligament dominance.[20] In case of ligament dominance, the supportive muscle groups that are adjacent to the knee joint do not contract, leading to the absorption of ground reaction forces by static tissues such as ligaments, cartilage, and bone. There are several studies demonstrating that ligament dominance is a risk factor for ACL tear, with demonstrated increased side-to-side differences in case of female subjects.[21,22] It seems that the posterior kinetic chain (gluteus, hamstrings, gastrocnemius-soleus) is of utmost importance in preventing ACL tears, even if all lower extremity muscular groups are responsible for dynamic knee steadiness. Improper dynamics of the muscles during landing leads to increased abduction times, thus increasing the load that is transmitted to the ACL.[20] Another neuromuscular imbalance creating a risk for ACL tear has been named as quadriceps dominance by Hewett.[20] This is described as a quadriceps-active landing technique; women activate their quadriceps muscular group more than men, resulting in a vertical extended landing posture rather than a flexed posture, with an increased protection for the ACL. Contraction of the quadriceps exerts a tension on the ACL, with a maximum in 0–30° of knee flexion. An upright landing position mainly contracts the quadriceps, applying an anterior shear stress to the knee joint.[23] Leg dominance is another face of neuro-muscular control, which refers to side-to-side asymmetry. Even if the majority of athletes have one dominant side for kicking or jumping, it seems that female athletes have increased side-to-side differences.[20,24] Hewett considered a sportsperson to be leg-dominant when the muscle asymmetry was measureable.[20] In a study published in 2003, Ford found that female basketball players landed with a significantly higher maximum valgus knee-angle on their non-dominant side in comparison with their dominant part, finding not valid for males.[22] The last neuromuscular misbalance described by Hewett is termed trunk dominance. This describes the lack of dynamic control of the trunk due to suboptimal core strength, generating larger movements in the lower extremity for compensation. Lateral trunk movement was the best predictor for ACL tear risk in a study published by Zazulak in 2007.[25]

Even if there might be not enough studies to definitively assign these factors as risk factors for ACL tears, the efficiency of preventing programs based on reducing neuromuscular imbalances support the importance of these factors. Fatigue might be a risk factor for ACL tears, described in a study published by Chappell in 2005, but there aren't enough data yet to firmly sustain the importance of this factor.[26] There are many studies analyzing environmental factors as risk factors for ACL injury. These include the sport, weather conditions, and especially sports gear, the quality of equipment, footgear, surface, shoe-surface interface etc. The most studied sports that seem to have the highest potential for ACL injuries are: American football, Australian football, soccer, basketball, handball, and ski.[27] Several studies showed a high risk of ACL tears in dry compared to wet conditions, in hot compared to cold season, or in pre-season.[28,29] Orchard in 2005 issued the results of a prospective study on Australian footballers and showed that grass type, additionally to ground hardness or weather conditions, would be accountable for a higher risk of non-contact ACL tears.[30] An epidemiologic study conducted by Dragoo *et al*. in 2012 analyzing football players, found that the percent of ACL tears on artificial grass compared to natural grass was present in games, scrimmages, and practices, and across all divisions.[31] Olsen in 2003 published a retrospective study on the Norwegian handball team and found an increased ACL tear risk on rubber floors.[32] Ekstrand *et al*. did not find any differences between the use of natural or artificial grass when conducting a prospective study on injuries on elite footballers.[33] It seems that there is scarce evidence to sustain the fact that increased friction forces in the shoe and ground surface are an important risk factor for ACL tears. Bere *et al*. published in 2011 a video analysis showing that ski equipment was the most important risk factor for ACL injury, followed by changes in snow conditions;[34] icy conditions on the slope probably could be safer than aggressive snow conditions. There are many studies supporting the importance of environmental factors in ACL injuries, some specific for certain sports.

PREVENTION PROGRAMS

Even if there are some contradictory results and more studies are needed, we can say that at least some of the described factors definitely have a significant role in producing non-contact ACL tears. Considering that some risk factors for ACL injury are modifiable, preventing programs have been developed with the purpose to reduce ACL tears. Most studies on preventive programs aimed to change risk factors for ACL tears rather than decrease injury incidence.[28,29] Even if male professional and recreational athletes comprise the biggest population of total ACL tears, the science behind prevention injury programs is based mainly on research conducted on female athletes, therefore researchers are not ready to offer optimal preventive plans for male sports players.[35] Prevention agendas center their attention on some key features of training: balance, proprioception, plyometrics, strengthening, endurance, and stability.[36] The first clinical research to examine the protecting mechanisms of a neuromuscular training schedule was carried out in 1999 by Hewett *et al*.[37] A group of athletes underwent a pre-season neuromuscular workout program focused on flexibility, plyometrics, and proper technique. They found an increased incidence of injuries in the untrained female group compared with the trained female group. In 2005 Mandelbaum *et al*. analyzed in a prospective study conducted on women soccer players the role of a prevention program they had developed, named Prevent injury and Enhance Performance (PEP), designed for ACL tear prevention.[38] The PEP program (Table 1) is a 20-minute exercise program that replaces the normal warm-up routine.[38] The study included 1,041 female athletes in the first year and 844 in the second year who underwent the program and were compared with matched athletes as control. There was an 88% decrease in ACL tearing within the 1st year, and a 74% decrease in the second one.

Using the PEP program Gilchrist *et al*. evaluated, in a randomized controlled trial, the incidence of non-contact ACL injury in women's soccer. They found that the incidence of non-contact ACL tears was 3.3 times lower in the PEP group compared to controls, and that players in the PEP group with a history of ACL tear had a significantly lower chance of suffering additional injuries.[39] Thompson *et al*., in 2016, published a study investigating the effects of the F-MARC 11+ injury prevention protocol developed by Soligard in 2008, showing that the program may be effective in improving peak knee valgus moment, a risk factor for ACL injuries, during a double-leg jump in pre-adolescent athletes. Also, the program reduced overall injury rates, but it remained unknown if it reduced ACL injuries in particular.[6,40]

Many trials analyzed different neuromuscular training programs designed to reduce the risk for ACL tear in handball female players and showed to reduce in the incidence of overall ACL injury, even if the studies are underpowered.[41] The efficacy of prevention programs in decreasing the incidence of ACL tearing was sustained by the results of meta-analyses published by Hewett in 2010[20], Yoo in 2010[36], and Sadoghi in 2012.[42] There are several biomechanical and clinical studies and meta-analyses supporting the possibility of preventing ACL injury by using validated prevention training programs, but we need future research to determine the importance of neuromuscular imbalances and generate solutions to prevent non-contact ACL injuries. One significant difficulty in the implementation of prevention programs is compliance. Steffen *et al*. published a study in 2007, in which adhesion to preventive programs was 24% of the number of teams, as a result

TABLE 3. Prevent injury and Enhance Performance designed for ACL injury prevention

Phase	Activity (Duration of Time To Complete Activity)	Time at which Activity Occurs During Workout	Purpose
Warm-up (purpose: preparation)	Jog line-to-line (30 sec)	0 to 0.5 min	Prepare for training session
	Shuttle run (side-to-side) (30 sec)	0.5 to 1 min	Engage hip abductors and adductors; promote speed; avoid inward caving of knee joint
	Backward run (30 sec)	1 to 1.5 min	Engage hip extensors and hamstrings
Strengthening (purpose: leg strength)	Walking lunges (1 min)	1.5 to 2.5 min	Strengthen quadriceps
	Russian hamstring (1 min)	2.5 to 3.5 min	Strengthen hamstrings
	Single toe raises (1 min)	3.5 to 4.5 min	Strengthen calf: improve balance
Pylometrics (purpose: power, strength, speed)	Lateral hops over cone (30 sec)	4.5 to 5 min	Increase power and strength: emphasise neuromuscular control
	Forward and backwards hops over cone (30 sec)	5 to 5.5 min	Increase power and strength: emphasise neuromuscular control
	Single leg hops over cone (30 sec)	5.5 to 6 min	Increase power and strength: emphasise neuromuscular control
	Vertical jumps with headers (30 sec)	5 to 6.5 min	Increase vertical jump
	Scissor jump (30 sec)	6.5 to 7 min	Increase vertical jump
Agilities	Forward run with 3-step deceleration	7 to 8 min	Increase dynamic stability of ankle-knee-hip complex
	Lateral diagonal runs	8 to 9 min	Encourage technique and stabilization of hip and knee; avoids “knock-knee” position
	Bounding rung (44 yd.)	9 to 10 min	Increase hip-flexion strength, power and speed
Stretching (can be performed after warm-up)	Calf stretch (30 sec × 2 repetitions)	10 to 11 min	Stretch calf; focus on lengthening muscle
	Quadriceps stretch (30 sec × 2 repetitions)	11 to 12 min	Stretch quadriceps; focus on lengthening muscle
	Figure four hamstring stretch (30 sec × 2 repetitions)	12 to 13 min	Stretch hamstrings; focus on lengthening muscle
	Inner thigh stretch (30 sec × 2 repetitions)	13 to 14 min	Stretch adductors; focus on lengthening muscle
	Hip flexor stretch (30 sec × 2 repetitions)	14 to 15 min	Stretch hip flexors; focus on lengthening muscle

of the fact that instructors and athletes choose to focus on their performance rather than preventing injuries.[43] This issue raises the question if prevention training programs should be applied to all athletes or just to the risk group. Myer *et al*. in 2013 conducted a screening study on women athletes divided into risk categories based on analyzing movement during a vertical jump and calculating knee abduction.[35] They showed that peak knee abduction angle, quadriceps-to-hamstring ratio, knee-flexion range of motion, body mass index, and tibial length were the best predictors for knee abduction moments, with a sensitivity of 77% to 85% and a specificity of 71% to 93%. In 2015, the American Academy of Orthopedic Surgeons published the Appropriate Use Criteria for ACL Injury Prevention programs in order to determine the usefulness of using a supervised program for preventing ACL tears.[44] Most votes were for an ACL injury prevention program that includes appropriate instruction and supervision, dynamic warm-up, strength training, technique training, plyometrics, balance and proprioceptive training.

CONCLUSIONS

An increase in ACL injuries has been seen in the past years due to the growing number of athletes today. Even if there is not one specific way to injure an ACL, there are several different factors that intensify the risk for a non-contact ACL tear. It is accepted that females have a four to six time higher risk of ACL injuries than males, due probably to many different intrinsic factors, such as anatomical, biomechanical, and hormonal. Understanding the neuromuscular factors and environmental factors of an ACL injury allows physicians and therapists to develop programs that help decrease the rate of such injuries.

CONFLICT OF INTEREST

Nothing to declare.

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JIM Journal of Interdisciplinary Medicine

REVIEW

ORTHOPEDICS // ARTHROSCOPIC SURGERY

Tips and Tricks in Total Knee Arthroplasty

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ARTICLE HISTORY

Received: April 26, 2017
Accepted: May 13, 2017

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ABSTRACT

Being a procedure that is more frequently used in orthopedic surgery and one of the most successful surgeries of the last century, total knee arthroplasty is still a challenge when it comes to matters such as anatomical reconstruction, mobility and stability of the lower limb. This paper reviews the main aspects of planning and surgical technique, by citing procedures that have proven their efficacy, returning very good results, not only on the short term, but also on the medium and long term. From a careful planning, even with personalized guides, to a swift postoperative recovery, total knee arthroplasty is being standardized, thus returning duplicable results and shortening the timespan of the surgical process. The use of tranexamic acid has led to a decrease in postoperative bleeding to 150–200 ml and to a decline in blood transfusion rates. Periarticular infiltrations with ropivacaine allow patients an immediate start for postoperative recovery, offering very good results in terms of mobility. Using state-of-the-art materials and methods with different surgical techniques and approaches, patients are offered a way through which normal life can be regained in a short period of time, with a complete recovery and a long survival that is close to 20 years.

Keywords: total knee arthroplasty, tranexamic acid, postoperative recovery

INTRODUCTION

Emerging as a common technique performed by orthopedic surgeons, total knee arthroplasty (TKA) represents a challenge in terms of anatomical reconstruction, alignment, ligament balancing, and stability of the involved lower limb.

Introduced in the post-war era of the last century, this technique has been subject of important adjustments in terms of materials used, surgical techniques, and, last but not least, postoperative recovery. With the passing of time, patients have become more active, more dynamic, wishing for a life as close to normal as possible, with a short rehabilitation period. Nowadays, TKA is considered a very successful technique, with a 10-year revision rate close to 12%, scoring as high as 70% in terms of patients' satisfaction.[1]

In order to maintain consistency in having the best possible results in knee arthroplasty, a number of conditions and aspects need to be met. As with every procedure, the smaller the deviation from the standard protocol, the better the expected outcome.

PREOPERATIVE PLANNING

The selection of patients is a crucial step, and the indication for the procedure is a knee with arthritis, painful, with an Ahlback score of III–IV, and unresponsive to standard treatment with painkillers and non-steroidal anti-inflammatory drugs (NSAIDs).

Radiological examination of the knee with loading, along with the measurement of the axes and angles of the surgically treated knee, gives very useful information in terms of mechanical alignment, but most importantly — which surgical bone corrections need to be performed intraoperatively.

A full and accurate clinical examination of the affected knee is essential to the evaluation of the stability and kinetics of the knee joint, and it orients the orthopedic surgeon to use either a primary prosthetic or one with an elevated level of constraint in the knee (Legacy Constrained Condylar Knee – LCCK, Hinge).

In recent years, the use of personalized guides has given the patients a very good alternative by considerably shortening the timespan of the surgical procedure, with a better bone mass preservation. In order to create personalized guides, it is imperative to perform a magnetic resonance (MRI) scan of the joint, based on which these guides will be 3D printed.

Based on the knee deformity (valgus, varus, flexum), different approaches can be taken into consideration.

SURGICAL APPROACHES

The midvastus approach is the most frequently used technique, its main advantages being the preservation of the quadriceps tendon and of the nervous and vascular structures, allowing a swift recovery. Its downside is a more difficult joint exposure by providing a poor patellar eversion.

The medial parapatellar approach allows a good patellar eversion, facilitating joint exposure even in patients with a high body mass index (BMI) and a minimal degree of flexum. The main disadvantage of this approach is a longer period for recovery.

The subvastus approach is more anatomical than the medial parapatellar approach, thus allowing the shortest recovery period, but having the downside of a more difficult exposure of the joint and a higher risk of neural and vascular damage due to its proximity to the adductor canal (Hunter's canal).

The lateral parapatellar approach is used in patients with advanced valgus and flexum deformity with external tibial rotation. It allows a fair exposure of the joint, but its disadvantage is that it cannot be used for cases in which the knees present varus deformity, which requires simultaneous tibial tuberosity osteotomy.[2–4]

Extended approaches (rectus snip and quadriceps turndown) are used in cases that present with locked knees and advanced ligament retractions, and it is the only option that allows adequate patellar eversion and joint exposure. The main disadvantage is the longer recovery period, which is associated with all extended approaches.

PERFORMING THE BONE CUTS

The principle of TKA is based on the restoration of the lower limb mechanical shaft. In this regard, there are two types of alignment: classical and kinematic. Physiologically, the angle of the femoral valgus is 5–6 degrees, while the tibia is aligned in neutral position (at 90 degrees). Hence, cuts that obtain 3–4 degrees of valgus are preferred for knees with valgus deformity, while cuts that obtain 5–7 degrees of valgus are preferred for knees with varus deformity.[5,6]

The femoral entry point is located at 0.5–1 cm from the anterior cruciate ligament insertion. Its malalignment can generate secondary varus/valgus or flexion/extension deformities.[5,6]

The joint space needs to be taken into consideration every single time. Landmarks that can be used for its evaluation are: 25–30 mm from the medial epicondyle, 10 mm from the peroneal head or the meniscal insertion on the capsule. If the joint space is modified, the extensor apparatus undergoes important alterations resulting in extension deficit and anterior compartment syndrome.[7]

The distal femoral cut is obtained with a 5–7-degree valgus, resecting 9–11 mm from the reference point, based on the type of implant. If there is a hypoplastic lateral femoral condyle, the reference point is chosen according to the position of the medial condyle.[5]

The femoral rotation is adjusted to the posterior condylar axis, to the transepicondylar axis, and to Whiteside's line. In case of knees with valgus deformity, with hypoplastic lateral femoral condyles, the previous reference point is preferred.[8,9]

The oblique and notch cuts are specific to the implant type, and are performed according to its own principles.

The tibial entry point is located anteriorly from the anterior cruciate ligament in a central position. The alignment guide can be either centromedullary or extramedullary, in regard to the shape of the tibial diaphysis. Extramedullary guide is preferred in patients with a very curved or narrow tibial diaphysis.[10]

The proximal tibial cut is performed by being adjusted to the healthy tibial area, ignoring defects, by resecting 10 mm with a 5 degrees posterior sagittal slope.

The rotation of the tibial component is adjusted to the tibial tuberosity and tibial crest, in the medial third of the plateau.[11]

LIGAMENT BALANCING

The principles of obtaining a properly balanced knee from a ligament standpoint is by achieving a flexion gap that is equal to the extension gap. The techniques by which ligament balancing is performed are listed below.

The ligament release

For knees with varus rotation, depending on the retraction of the structures, the ligament release presents the following sequence of structures: (1) medial osteophytes at the level of the tibia and femur; (2) deep medial collateral ligament; (3) semimembranous insertion; (4) the medial collateral superficial ligament; (5) pes anserinus; (6) the posterior capsule.[12]

For knees with valgus rotation there is no consensus about the release sequence, therefore the technique presents several alternatives. The Krackow technique comprises in releasing the ilio-tibial tract first, followed by the lateral collateral ligament, the posterolateral capsule, and the bicipital tendon.[13] With the Insall method, the posterolateral capsule is released initially, followed by the lateral collateral ligament, the popliteal tendon, the ilio-tibial tract, and the intermuscular fascia. The release sequence in the Whiteside procedure is as follows: lateral collateral ligament, popliteal tendon, ilio-tibial tract, and posterior external capsule, while the Keblish sequence includes the release of the ilio-tibial tract, the lateral collateral ligament, the popliteal tendon, and the posterior external capsule.[2]

For knees that are locked in flexion, the release sequence is as follows: (1) posterior osteophytes of the tibia and femur; (2) posterior capsule detachment; (3) medial and lateral capsule detachment; (4) transverse incision of the posterior capsule; (5) redoing the femoral cut; (6) elevation of the joint space.[6]

For genu recurvatum, correction is performed through a wider tibial and femoral resection and with adding a larger size insert.

"Pie-crusting" technique

Described by Insall, this technique is performed with the knee in extension, after the femoral and tibial cuts are performed. The goal is to obtain an equal rectangular extension gap. It can be done both medially and laterally. Caution is advised, as the external popliteal nerve is located in the proximity of the capsule and can be damaged.[14]

A size 11 blade is used for puncturing of the structures in a pie-crusting manner while applying a varu/valgus stress depending on location.[15]

BLOOD LOSS MANAGEMENT

Perioperative blood loss can be important, as it ranges from 300 mL to 2 liters in some cases. Therefore, a rigorous approach in this regard involves the use of a hemostatic tourniquet,[16] hemostasis with a mono- or bipolar cautery, and using systemic or local tranexamic acid.[17,18]

Tranexamic acid is given before the surgery, usually 30 minutes before tourniquet inflation. One gram is administered intravenously.[18] During surgery, 30 minutes before the tourniquet is deflated, another gram is administered intravenously.[18] In the immediate postoperative period, 3 grams of tranexamic acid diluted in 100 ml of NaCl are injected through the intraarticular drainage tube, which is clamped for 4 hours. After tranexamic acid administration, the average postoperative bleeding is reduced to 100–200 mL.

PAIN MANAGEMENT

Methods for treating postoperative pain

Pain occurring after TKA should be managed in a systematic fashion, with initiation of treatment after the etiology of the pain has been identified. The pharmacological management of postoperative pain following TKA includes preoperative treatment with NSAIDs, COX2 inhibitors, and pregabalin, as well as oral and intravenous postoperative analgesia (acetaminophen, tramadol chlorhydrate, oxycodone).[19] Other methods include neuraxial or peridural analgesia, peripheral nerve blocks (sciatic and femoral), intraoperative periarticular infiltration.

Intraoperative periarticular infiltration

The intraoperative periarticular infiltration is performed with a mixture of 40 mL of 1% Ropivacaine with 100 mL of NaCl 0.9% solution. Three 50 mL syringes will be mixed with adrenaline, after which the mixture is loaded into them. Prior to cementation, periarticular injections are administered as follows: the suprapatellar bursa and quadricipital tendon, the medial retinaculum, the medial collateral ligament, the posterior collateral ligament insertion, the lateral collateral ligament, the lateral retinaculum, and Hoffa's fat pad (infrapatellar fat pad).[20]

CONCLUSIONS

The standardization of total knee arthroplasties in association with careful planning and the use of personalized 3D-printed guides has led to the achievement of duplicable results and shortening of the overall operative time, with lesser hemorrhagic complications and a proper pain management before, during, and after the procedure. Ligament balancing is an essential step in the TKA procedure, as it contributes to the overall postprocedural success, including increased joint stability, reduced pain, and decreased rates of revision surgeries. By using state-of-the-art materials and methods with different surgical techniques and approaches, patients are offered a way through which normal life can be regained in a short period of time, with a complete recovery and a long survival that is close to 20 years.

CONFLICT OF INTEREST

Nothing to declare.

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Journal of Interdisciplinary Medicine

ORIGINAL RESEARCH

ORTHOPEDICS // ARTHROSCOPIC SURGERY

Anatomic All-Inside Anterior Cruciate Ligament Reconstruction Using the TransLateral Technique

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Received: April 24, 2017
Accepted: May 13, 2017

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ABSTRACT

Background: Anterior cruciate ligament (ACL) reconstruction is a commonly performed procedure and considered to be the gold standard in restoring knee function and stability in ACL-deficient knees. The TransLateral all-inside technique implies the use of only two portals – anterolateral and anteromedial, without the use of an accessory portal. The work is done using the lateral portal, while the medial portal serves as a viewing site. Only a few studies have been published regarding the assessment of the functional and clinical outcomes of this novel technique. **Aim of the study:** To determine the clinical effectiveness of the TransLateral procedure used for ACL reconstruction and its ability to re-establish joint functionality and stability in ACL-deficient knees. **Material and methods:** A prospective study was conducted at the Orthopedics and Traumatology Clinic no. 2 in Tîrgu Mureș. Thirty-two patients matched our inclusion criteria and were operated using the TransLateral technique for ACL reconstruction. Outcome assessment was performed using the Knee injury and Osteoarthritis Outcome Score (KOOS), the Lysholm score and the Tegner Activity Scale. The questionnaires include items referring to pain, physical functioning, sports activities, and quality of life. Operative time and ACL graft size were also documented. **Results:** All patients underwent single-bundle ACL restoration using a quadrupled semitendinosus tendon. Out of 32 patients, 21 had associated meniscus lesions and 8 collateral ligament injuries. Mean graft diameter was 8.7 mm and mean length 63.2 mm. Significantly improved KOOS values were found at 12 months post-surgery regarding the mean baseline score: 59.3 ± 5.3 vs. 95.3 ± 4.9, p <0.0001. The Lysholm score improved from a mean of 56.3 ± 4.9 to 93.9 ± 5.6, p <0.0001 at the end-point. The Tegner activity scale ranged from 3.8 ± 1.9 to 5.9 ± 2.4, p <0.0001 at the final follow-up. **Conclusions:** The TransLateral technique proved its clinical effectiveness and its ability to restore knee stability after ACL reconstruction surgery.

Keywords: TransLateral, all-inside, anterior cruciate ligament

INTRODUCTION

Anterior cruciate ligament (ACL) reconstructions (ACLR) are the most frequent surgical interventions related to sports injuries worldwide. The incidence of ACL ruptures was 30 cases/100,000 individuals in 2008, the number of reported cases increasing every year.1 One of the fundamental principles in orthopedics is restoring the functional anatomy of the affected structure. As it has an insignificant healing capability, arthroscopic reconstruction of the ACL is the gold standard technique in active individuals who decide to continue sports and athletic activities.2–4 Several innovative techniques sought to provide elite outcomes after the reconstruction with fewer invasive drills, less complications on the long run, and shorter post-operative rehabilitation time.5–9 One of the classic and most frequently used techniques implies the usage of transtibial drilling in order to create the femoral tunnel. Therefore, the placement of the femoral tunnel depends crucially on the position of the transtibial drill, and a vertical malposition of the femoral tunnel can occur.10 Even with positive reported outcomes, this technique is not considered to entirely restore the anatomic position of the native ACL.11 A new concept frequently referred to as "anatomic" reconstruction of the ACL has been described in the literature, and biomechanical outcomes proved its superiority compared to non-anatomic reconstructions.12–15 The anatomic technique implies the use of a medial accessory portal through which the femoral tunnel is prepared.16 The technique is correlated with reduced surgical invasion and pain, earlier recovery after the reconstruction, shorter hospitalization times, and better cosmetic outcomes due to fewer incisions.17–20

Our objective was to determine the clinical effectiveness of the TransLateral technique used for ACL reconstruction and its ability to restore joint functionality and stability in ACL-deficient knees.

MATERIALS AND METHODS

A prospective, single-center study was carried out in the Orthopedics and Traumatology Department no. 2 in Tîrgu Mureș, Romanian between August 2015 and September 2016. All patients who presented to the outpatient clinic with an ACL-deficient knee were screened for inclusion in the study. Each patient was informed regarding the pros and cons of the available techniques. Out of 43 patients screened for inclusion, 32 opted for the all-inside technique using semitendinosus tendon as a graft for the new ligament. Exclusion criteria involved: multi-ligament injuries, revision cases, chondral or subchondral lesions higher than grade 2 Outerbridge classification, and patients aged under 16 years, where bone maturity is not complete.17 Each patient was operated by the same surgical team that had a two-year experience with the technique. The minimum follow-up period was set at 12 months. There were two scheduled follow-ups, at 6 and 12 months post-operative.

Brief description of the TransLateral technique

In order to work around the distal segment of the lateral condyle of the femur, laterally and to avoid the impingement on the patella tendon medially, special instruments are needed that were described by Logan *et al.* These include: an Opes radiofrequency probe (Arthrex Ltd, Naples, Florida, USA) used for soft tissue debridement; a curved marking/measuring equipment and an anatomical aiming arm for a retrograde drill; and a FlipCutter Arthrex. The patient is in supine position with a tourniquet applied through the intervention. Compared to the classical technique, the anterolateral portal is slightly lower and more medially. The anteromedial portal is usually created the traditional way or slightly lower. Arthroscopic evaluation and semitendinosus harvest and preparation are completed using the conventional method. The Opes radiofrequency probe is used for optimal debridement and grounding of the native ACL footprint after anatomic landmarks are identified. Two measurements are made afterwards, and using the device's sharp points, the femoral tunnel placement is established. The FlipCutter equipment is introduced within the lateral portal at the anatomical origin of the femur. An outside-in drilling is subsequently performed with the knee at 90° of flexion antero- and retrograde. Next, the graft is inserted and fixed with a TightRope Arthrex on the femoral side and a bioresorbable screw on the tibial part.21

Outcome evaluation tools

Using a simple questionnaire, demographic data was collected by a study nurse at the time of enrolment. Operative time, ACL graft size and range of motion were documented. Anterior knee laxity was measured in 25° of flexion using a RolimeterTM, Aircast® compact arthrometer. Patient-reported evaluation tools included the Knee Injury and Osteoarthritis Outcome Score (KOOS), the Lysholm score and the Tegner Activity Scale. KOOS was created with the purpose of evaluating short- and long-term symptoms and function in individuals with knee injury and osteoarthritis.22 It has five separate subscales with 42 items in total: a) pain, b) other symptoms, c) function in daily living, d) function in sport and recreation, and e) knee-related quality of life. The score is a percentage score ranging from 0 to 100, 0 representing severe problems and 100 representing no difficulties. The Lysholm Score is regularly applied

TABLE 1. Demographic characteristics

Variable	Value
Age, mean ± SD, y	29.1 ± 7.6
BMI, mean ± SD	25.2 ± 4.2
Gender, male/female, n	21/11
Time from injury to surgery, mo, mean ± SD	13 ± 23.2
Follow-up period, mo, mean	13.1
Cartilage defects Outerbridge I/II, n	11
Associated meniscus lesions, n	
Lateral	8
Medial	13
Associated collateral ligaments injury, n	
Lateral	1
Medial	7

TABLE 2. Range of motion and knee laxity results

	Extension*	Flexion	Laxity**
Preoperative, mean	−0.9°	133.2°	10.9
6 months, mean	1.4°	136.9°	6.2
12 months, mean	0.5°	139.1°	6.2

*negative value represents hyperextension beyond the 0° point
**values reported in millimeters

to assess the results of knee ligament operations. The current version contains 8 subscales: limp, support, locking, instability, pain, swelling, stair climbing, and squatting. Values from each subscale are summed in order to provide a total normalized score. The score varies from 0 to 100, a higher value representing an improved outcome: excellent 95–100; good 84–94; fair 65–83; poor <64. The Tegner Activity Scale seeks to offer a standardized system of grading functional daily and sports activities. It is frequently used in combination with the Lysholm Score to evaluate subjects with ACL injuries and reconstructions.23 A score of 0 is equivalent to retirement or disability due to knee-related injuries, while a score of 10 corresponds to involvement in elite competitive athletic activities.

Statistical analysis

Statistical analysis was used to compare outcomes for every follow-up stage before the surgery and at 6 and 12 months after surgery. Differences between the scores were analyzed using chi-square, t-test and one-way repeated ANOVA. The statistical significance was set at an alpha coefficient of 0.05. All calculations were performed using GraphPad InStat (GraphPad, San Diego, USA) and EpiInfo v. 7.1.4.0 (Centers for Disease Control and Prevention, Atlanta, USA).

RESULTS

The expected follow-up time was reached for each patient without any graft rupture during the one-year follow-up. There were no major postoperative complications, except a case with a small infection on the anteromedial portal incision. Out of 21 patients who had meniscus-associated lesions, 14 were repaired with a standard meniscal all-inside suture. Other demographic characteristics are presented in Table 1.

Mean operative time tourniquet time was 74.1 minutes (range 43–111 minutes) after sterile surgical dressings were applied. The mechanism of injury occurred during athletic activities in 17 (53%) patients, with a valgus-twisting deceleration movement reported in 9 out of 17 cases. Concomitant injuries involved meniscus lesions in 21 (66%) cases, collateral ligament injuries in 8 (25%) cases, and cartilage defects in 11 (34%) cases.

The mean graft diameter was 8.7 mm and mean graft length was 63.2 mm (range 54–70 mm). Range of motion was measured for both injured and uninjured knees before and after surgery. There were no differences in extension or flexion between the injured and uninjured knees before the surgery. Table 2 includes mean flexion-extension results and anterior knee laxity for each follow-up.

TABLE 3. Outcomes from the KOOS*, Lysholm score and Tegner Activity Scale

	Preoperative, mean ± SD	6 months, mean ± SD	12 months, mean ± SD	P value**
KOOS	59.3 ± 5.3	74.6 ± 11.1	95.3 ± 4.9	<0.0001
Lysholm score	56.3 ± 4.9	72.6 ± 9.8	93.9 ± 5.6	<0.0001
Tegner Activity Scale	3.8 ± 1.9	5.8 ± 1.1	5.9 ± 2.4	<0.0001

*Knee Injury and Osteoarthritis Outcome Score
**preoperative and 12 month follow-up comparison

Subjective outcomes from the KOOS, Lysholm score and Tegner Activity Scale for each follow-up are presented in Table 3. The KOOS score improved significantly at 6 months after reconstruction (p <0.0001). The Lysholm score and Tegner Activity Scale also improved significantly from baseline preoperative scores at six months post-surgery. At the conventional radiograph follow-up, TightRope button positioning was precise in all patients. No differences in regards to KOOS, Lysholm score and Tegner Activity Scale were present in patients with associated lesions added to the ruptured ACL.

DISCUSSIONS

The all-inside technique has been used for ACL reconstruction for several years, but its clinical and functional effectiveness has not yet been rigorously evaluated. The key finding of our study is that the TransLateral all-inside anatomic reconstruction was able to provide stability to the affected knee 6 months post-surgery. Pain and function were two major outcomes to be evaluated, and the technique provided remarkable results. No complications and limitations regarding range of motion or joint functionality were documented. Subjective evaluation tools such as the KOOS, Lysholm score and Tegner Activity Scale improved significantly, even after six months post-reconstruction.

In a two-year follow-up trial using the TransLateral technique on 108 subjects, Yasen *et al*. concluded that this technique demonstrated good mid-term subjective and objective outcomes.15 Another trial on 92 individuals using the all-inside technique sought to prove its clinical effectiveness and functional efficacy.24 The Visual Analog Scale was used to evaluate subjective pain intensity and there were significant changes at 24 months of follow-up compared to baseline (5 vs. 0.1, p <0.0001). The Lysholm Score was 53.4 at baseline vs. 91.1 at 12 months (p <0.0001), and the Tegner Activity Scale was 2 at baseline vs. 5.5 at 12 months (p <0.0001), thus showing similar results to ours at one year post-reconstruction.

Classic transtibial drilling may be associated with non-anatomic positioning of the reconstructed graft, and the vertical femoral tunnel settlement may result in residual rotational knee instability.25,26 The TransLateral technique has the advantage of offering a better and more accurate femoral socket placement, by providing a clear view of the lateral condyle of the femur using the medial portal whilst operating from the lateral side.15 Additionally, it has been proven that drilling the femoral tunnel through a transtibial approach drives surgeons to have a tendency of drilling the tibial tunnel more posteriorly in order to have a precise placement on the femoral tunnel.27,28 Transportal drilling is therefore considered superior by allowing the operator to independently place and drill the femoral tunnel. Based on our results, we support this statement.

A recently published randomized controlled trial showed that the all-inside technique has less postoperative pain and rescue analgesics usage compared to other conventional techniques to date.29 Another randomized trial compared the outcomes of standard ACL reconstruction and all-inside technique.30 The subjective outcomes were similar, with no differences between the two techniques. However, pain after the first day of surgery was significantly lower in the all-inside group. The TransLateral technique also has the important advantage of preserving the gracilis muscle tendon, therefore protecting the hamstring strength and reducing postoperative rehabilitation time.31

There are some limitations to this study that should be mentioned. The use of a control study lot might bring a greater impact to the results and better potential recommendations. Also, the sample of patients might be considered too small compared to other published trials. Including patients with associated lesions added to ACL rupture may also incorporate biases, but an isolated rupture is considered rare. Another limitation is the absence of subjective pain assessment that could otherwise convey a different approach to the reported outcomes.

CONCLUSION

The TransLateral technique proved to be effective in restoring instability in ACL-deficient knees at one year post-reconstruction. Functional and clinical evaluation has shown promising results with accelerated rehabilitation, no range of motion limitation, and overall confident outcomes. When using this technique, all the work is performed within the lateral portal, while all the viewing is completed with no obstruction through the medial portal.

CONFLICT OF INTEREST

Nothing to declare.

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CLINICAL UPDATE

ORTHOPEDICS // ARTHROSCOPIC SURGERY

Autograft Options for ACL Reconstruction. Which Is Best?

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ARTICLE HISTORY

Received: April 29, 2017
Accepted: May 14, 2017

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ABSTRACT

Anterior cruciate ligament (ACL) tears are commonly seen in orthopedic practice, and usually restoration is recommended to re-establish normal knee function. Autografts and allografts are viable options. Among autografts the main sources are the patellar tendon, the hamstrings and the quadriceps tendon, each having advantages and drawbacks. Many factors should be taken into consideration when deciding on a graft source for ACL restoration; however, clinical data may aid the surgeon in choosing the right graft for every specific patient in an individualized manner. This short review is intended to highlight the main characteristics and clinical data for each type of autograft.

Keywords: anterior cruciate ligament restoration, autograft, bone-to-bone grafts, hamstring grafts, quadriceps tendon

Anterior cruciate ligament (ACL) tears are commonly seen in orthopedic practice among patients involved in different sports activities, and usually, ACL restoration is recommended to re-establish normal knee function. Autografts are very frequently used for the reconstruction, and the most commonly used are the bone-patellar tendon-bone (BTB) and the four-strand hamstring tendons (HT) grafts.[1,2] Of these two, in terms of clinical results, there is no clear evidence of one's superiority over the other, at least not with a clear significance.[3–5] However, with regard to graft-associated morbidity, HT are recognized as providing less donor site morbidity compared to BTB grafts.[6–8] Recently, there has been an increase in interest in the quadriceps tendon (QT) as an autologous graft option for ACL restoration.

In terms of strength and stiffness, the native ACL resists at a maximum tensile load of about 2150 N and has a stiffness of around 240 N/mm.[9] A 10 mm BTB graft has been found to resist to tensile loads of up to 2977 N, with a stiffness of about 620 N/mm.[10] A 4-strand HT graft has a tensile load of up to 4000 N, with a stiffness of about 750 N/mm.[11] For the quadriceps tendon graft with a 10 mm diameter the numbers are similar with the BTB graft, having a maximum tensile load of about 2150 N, with a stiffness of about 460 N/mm.[12]

In terms of graft incorporation times, the BTB autograft has the fastest rate of incorporation in the tunnels with the bone-to-bone interface, about 6 weeks, this being one of the most important advantages of this graft. The hamstring graft has an incorporation time of about 12 weeks, and the quadriceps graft takes about 6 to 12 weeks to integrate in the tunnels.

Donor site morbidity is another important aspect to consider when deciding on a graft for ACL restoration. In general, the patellar tendon graft is recognized as the graft with the highest harvest site morbidity including anterior knee pain, kneeling pain, and patellar fracture.[13] Some of these complications can be reduced with different techniques of harvesting the graft.[14] HT grafts are described as being the least morbid graft option for ACL reconstruction. However, disruption of the infra-patellar branch of the saphenous nerve, premature amputation of the graft, and other complications related to harvest have been described. One important drawback of this graft is the inconsistent size and the inability to measure it preoperatively on the MRI. Another disadvantage is the loss of power in knee flexion, which can be significant in certain sports activities.[15] The quadriceps graft is the least studied option for ACL reconstruction, but it seems to have a low morbidity. If used as a free-bone plug graft, the risk of patella fracture is eliminated.[16] Compared to harvest-related pain, it seems to be even less painful than HT.[17] Other advantages reported with the quadriceps graft are predictable size, great versatility, and the ability to harvest grafts in different widths, thicknesses, and lengths, both for single- and double-bundle techniques.[18,19]

With regard to clinical results, a large amount of data exists comparing BTB and HT. In a meta-analysis by Poolman *et al.* (2007), they showed reduced morbidity using a HT autograft for ACL reconstruction. The authors stated that the recent endobutton hamstring graft fixation method (2 studies) showed comparable stability to BTB grafts in the Lachman test.[20] In another meta-analysis by Biau *et al.* that included 6 randomized clinical trials in which 423 subjects with symptomatic unilateral ACL damage were randomly assigned to reconstruction with patellar tendon or HT autograft, postoperative knee instability was less common after ACL restoration with patellar tendon autograft than with HT autograft.[21] The difference was noted especially in case of the pivot-shift and for females and younger patients. Reinhardt *et al.* showed in a systematic review a lower graft failure rate for BTB than for HT (7.2% vs. 15.8% respectively, $p = 0.02$).[22] Magnussen *et al.* showed in a systematic review lower graft failure rates for BTB compared to HT, but without statistical significance.[6] There was no difference in patient-reported outcomes (International Knee Documentation Committee, IKDC). Anterior knee pain and kneeling pain were higher for BTB. More recently, in 2015, Xie *et al.* showed no difference in re-tear rate between the patellar tendon and hamstrings, and no difference for patient-reported outcome measures. However, reconstruction with patellar tendon graft resulted in better rotational stability and return to pre-injury level of activity. Again, anterior knee pain and kneeling pain were greater for BTB.[3] Also, some registry studies show a higher overall risk of revision in patients with HT graft compared to BTB graft.[23]

When looking at the quadriceps graft, there is little published data compared to the other mentioned grafts. Lund *et al.* did not find any differences in anterior knee pain and functional outcomes in a prospective randomized trial comparing the QT with the patellar tendon. However, knee walking pain was significantly less in case of the QT compared to BTB.[24] A systematic review by Slone *et al.* in 2014 showed no difference for stability, range of motion, functional outcomes, and complications between the quadriceps graft and BTB. Also, less donor site morbidity was found in case of QT.[25]

An interesting study by Ma *et al.* that aimed to study the differences associated with graft maturity on magnetic resonance imaging, found that graft maturity was better at 6 months following ACL reconstruction with QT compared to HT autograft.[26]

CONCLUSIONS

In conclusion, autografts for ACL reconstruction provide similar functional outcomes. Bone-to-bone grafts are associated with higher rates of extension deficits, anterior knee pain, and kneeling pain, but have faster incorporation in the tunnels.

Hamstring grafts show slightly higher failure rates, especially when they are less than 8 mm in diameter; however, this could theoretically be managed by technical aspects such as the 5–6 strands grafts. Also, there is the concern of losing deep flexion strength, which may be important, especially in some specific sports.

Quadriceps tendons seem to be very versatile grafts. In general, the results are similar with BTB, but with less donor site morbidity.

Many factors should be taken into consideration when choosing a graft source for ACL reconstruction, including the surgeon's experience, tissue availability, and the patient's option and degree of activity. Based on the available data, BTB may be recommended especially for hyper-mobile patients and young, highly active patients with closed growth plates. HT may be recommended for patients with activities that require frequent kneeling and for skeletally immature patients, and the QT graft for hypermobile, highly active or female patients, and for knee flexion athletes with kneeling requirements.

CONFLICT OF INTEREST

Nothing to declare.

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