RECONSTRUCTION OF THE POSTERIOR CRUCIATE LIGAMENT

ESSAY

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In

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Introduction

The knee joint is one of the most frequently injured joints because of its anatomical structure, its exposure to external forces , and the functional demands placed on it.

(Fischer et al.,1991).

The stability of the knee joint depends on ligaments, tendons and muscles. The posterior stability of the knee depends mainly on posterior cruciate ligament and posterolateral structures of the knee which form a mechanical linkage that guides the movement of the bones relative to each other during flexion and extension.

(Kim et al.,2000).

The posterior cruciate ligament injuries have a reported incidence of between 3-37% of the knee injuries.

(Shino et al.,1995).

The most common mechanism of injury is motor vehicle accidents or direct force to proximal anterior tibia. Also, sports related injuries result from hyperextension of the knee with the foot typically planter flexed. The common mechanisms of posrterolateral instability are posrterolaterally direct blow to the medial part of the tibia that cause knee hyperextension.

(Mooney and Paulos.,1995).

The diagnosis of injury to posterior cruciate ligament and posrterolateral structures of the knee depends on the patient history of the trauma and the history of the mechanism of injury, physical examinations which may need general anaesthesia in acute knee injuries because of sever pain and muscle spasm. The use of different imaging modalities as x-ray, C.T. scan, M.R.I., ultrasono-graphy and arthrography are also used to confirm the diagnosis.

(Anderws et al.,1994).

The treatment of posterior cruciate ligament injuries is usually conservative if it is isolated injury grade I and grade II but the treatment is usually surgical in grade III or combined injury with other ligaments of the knee. In cases of bony avulsion of posterior cruciate ligament, surgical treatment is strongly indicated.

(Kim et al.,2000).

Anatomical considerations

Developmental anatomy:

The development of the knee joint and its component structures has been the topic of many elegant and detailed embryologic investigations in both humans and animals. Studies have shown that the knee joint develops as a cleft between the mesenchymal rudiments of the femur and tibia in about the eighth week of development. *(Ellison et al., 1985)*

As the mesenchyme in the region of the future knee joint condenses to form the precartilage of the joint and joint capsule, some vascular mesenchyme becomes isolated within the joint. This tissue is the precursor to the intra-articular structures of the knee (cruciate ligaments and menisci). *(Insall 1984)*

The cruciate ligaments of the human knee joint first appear as condensations of vascular synovial mesenchyme at about 7-8 weeks of development. At 10 weeks the anterior and posterior cruciate ligaments are separate from each other and are easily distinguished from one another by the direction of their parallel fibers. *(Ellison et al., 1985)*

Over the next 4 weeks the cruciate ligaments become better differentiated from the adjacent tissues and the attachment sites appear to be more specialized. Blood vessels are also seen in the loose tissue surrounding the cruciate ligaments at this time. *(Ellison et al., 1985)*

By 18 weeks the cruciate ligaments stand almost alone, and a few vascular elements are to be found within their substance. During the following weeks the chief changes in addition to growth, are the increase in vascularity and the appearance of define fat cells in the mass of connective tissue anterior to the cruciate ligaments and inferior to patella; thus the infrapatellar fat pad comes into being at this time. By 20 weeks the cruciate ligaments resemble those of the adult and their remaining development consists of marked growth with little change in form. *(Ellison et al., 1985)*

Gross anatomy:

This ligament is a complex structure that arises from the posterior tibia 1cm below the joint line and extends anteromedially to the lateral surface of the medial femoral condyle. Synovium that is reflected from the posterior capsule surrounds the medial, lateral and anterior border of the ligament, whereas the posterior aspect of the ligament is closely associated with the posterior capsule and periosteum. i.e extra synovial. (Fig. 1). *(Van et al., 1989)*

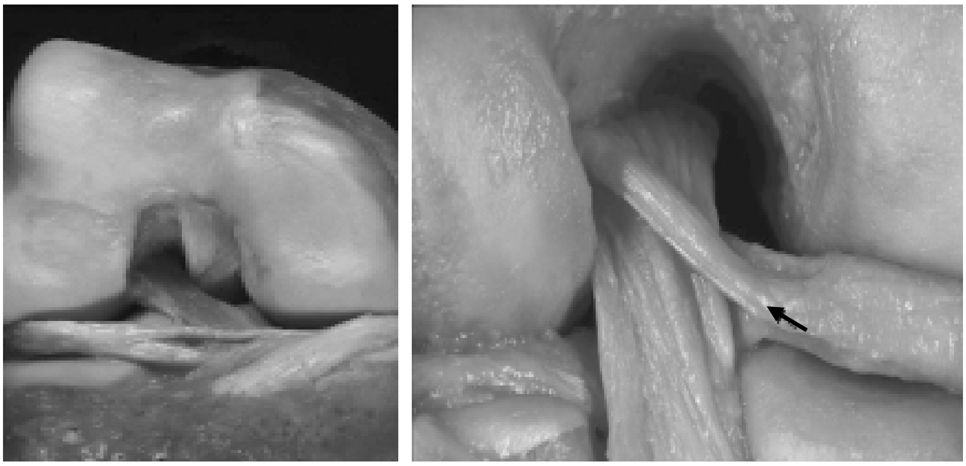

Fig. 1. Anterior (**a**) and posterior (**b**) anatomical view of the right knee. Note the wide anterior insertion of the posterior cruciate ligament on the lateral aspect of the medial femoral condyle and the relations with the Wrisberg's ligament (as indicated) posteriorly. (From Margheritini et al., 2001).

The posterior cruciate ligament averages in length between 32 and 38mm and has a cross-sectional area of 31.2mm at its midsubstance level, which is 1.5 times that of the anterior cruciate ligament cross-sectional area. Its femoral and tibial insertion sites are approximately three times larger than the cross-sectional area at the midsubstance level of the ligament. *(Van et al., 1989)*

Very few fibres of the posterior cruciate ligament behave isometrically, with most of the fibres lengthening upon knee flexion. The large ligamentous insertion sites and the lack of isometry within the fibres of the posterior cruciate ligament complicates the task of designing a posterior cruciate ligament reconstruction technique that adequately recreates the anatomical and biomechanical properties of the intact posterior cruciate ligament. *(Hefzy et al., 1986)*

The posterior cruciate ligament consists of two functional components referred to as the anterolateral and the posteromedial bundles. The distinct insertion sites of these two bundles on the tibia and femur are approximately equal in size. The anterolateral bundle is two times larger in cross-sectional area than the posteromedial bundle. Functionally, the two components have different tensioning patterns that depend on the degree of knee flexion. During passive flexion and extension of the knee, the anterolateral bundle is more taught in flexion and lax in extension. Conversely, the posteromedial bundle is more taught in extension and lax in flexion. (Fig. 2). *(Clancy et al., 1998)*

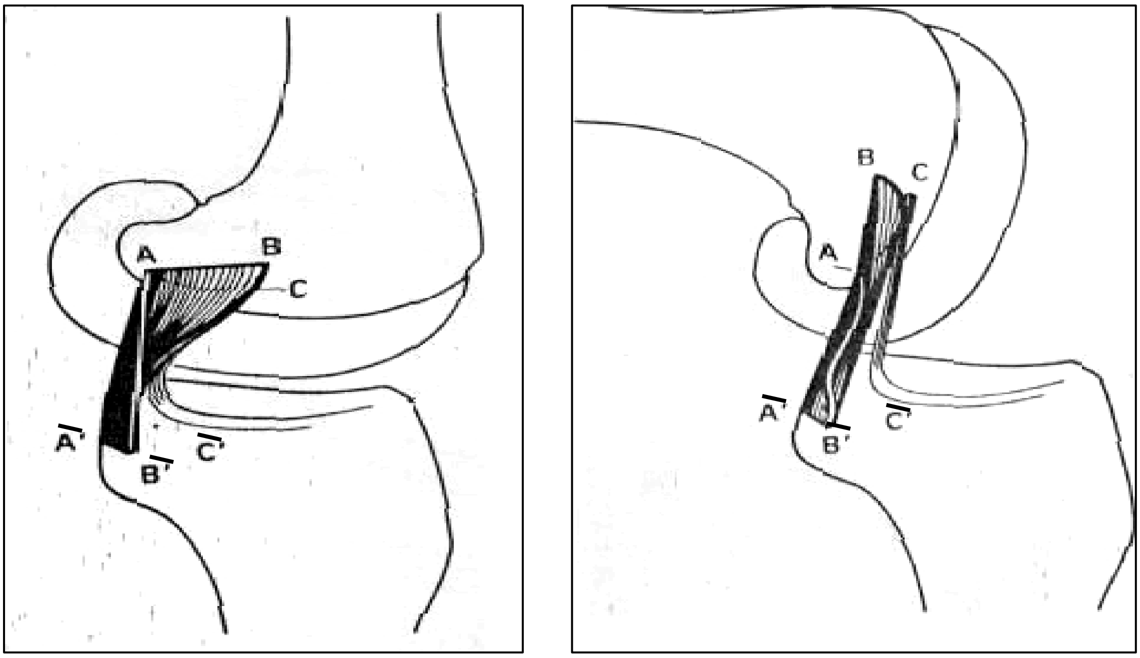

Fig.2. The changing tension in posterior cruciate ligament fibers as the knee is flexed to 90 degrees from full extension. A-A', smaller poster-omedial band; B-B', larger anterolateral band; C~C', ligament of Humphry. (From Girgis et al.,1975)

In addition to the anterolateral and posteromedial bundles, there are two meniscofemoral ligaments closely associated with the posterior cruciate ligament the ligament of Humphry (anterior) and the ligament of Wrisberg (posterior). They originate from the posterior horn of the lateral meniscus, run along side of the posterior cruciate ligament, and insert anterior and posterior to the posterior cruciate ligament on the medial femoral condyle. (Fig. 3) *(Kusayama et al., 1994)*

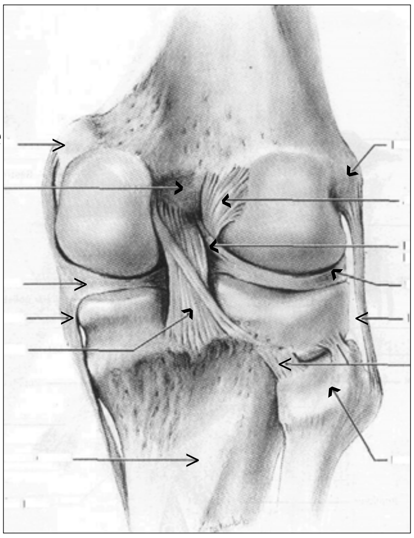

Fig.3. The posterior aspect of the knee, demonstrating the anatomy of the posterior cruciate ligament, meniscofemoral ligaments, and popliteus. (From Warren et al.,1981)

The presence of these ligaments is highly variable and discrepancies exist in the literature regarding their prevalence. The importance of the meniscofemoral ligaments has not been fully characterised, but they are believed to be significant anatomic and biomechanical structures that provide stability to the lateral meniscus. *(Harner et al., 1995)*

Posterolateral Structures:

The anatomy of the lateral and posterolateral aspects of the knee is complex and infrequently dissected surgically. Many of the previous anatomic descriptions have contained inconsistent terminology with regard to the structures in this area. Adding to this confusion is the fact that the anatomy is somewhat variable. The terms short lateral ligament and fabellofibular ligament have at times been used interchangeably. (Fig. 4) *(Kaplan,.1981)*

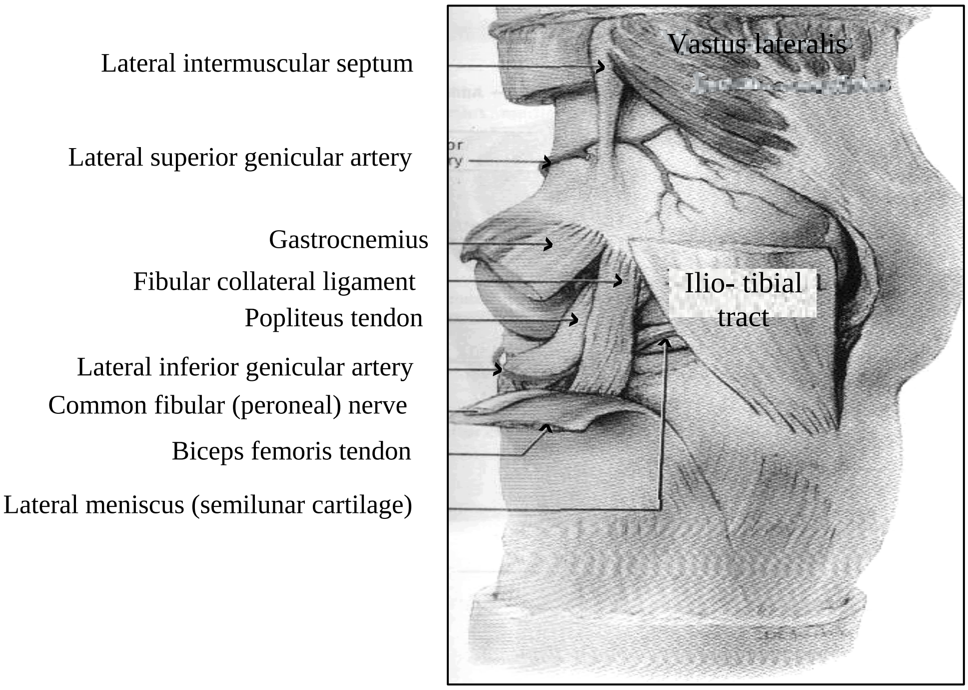

Fig.4:The anatomy of the lateral aspect of the knee (from Seebacher et al., 1982)

Kaplan has comprehensively reviewed the anatomy and the history of the terminology relating to these structures. There has also been confusion between the arcuate ligament and the arcuate ligament complex. The arcuate ligament is a Y-shaped structure that passes from the fibular head over the popliteus muscle and is continuous with the oblique popliteal ligament of **Winslow**. Although it is often seen as a thin structure, it is not synonymous with the term arcuate ligament complex. The arcuate ligament complex, as defined by **Hughston**, refers to the lateral collateral ligament, the arcuate ligament, the tendinous and aponeurotic portions of the popliteus muscle, and the lateral head of the gastrocnaemius.

(Kaplan ,.1981)

When exploring the traumatizcd tissues on the posterolateral side of an acutely injured knee, **Seebacher and colleagues** organized the anatomy of this region into three layers. *(Seebacher et al,.1982)*

The most superficial layer (***layer I***) has two parts: the Iliotibial tract and its expansion anteriorly, and the superficial portion of the Biceps Femoris and its expansion posteriorly. Anteriorly ***layer I*** extends to the patella and includes the layer of the prepatellar bursa. At the level of the distal femur the peroneal nerve lies deep to layer l,just posterior to the biceps tendon. ***Layer I*** is thickest where most of the fibers of the iliotibial tract and biceps are longitudinally oriented. At its insertion the biceps divides into a superficial layer and a deep layer, with the lateral collateral ligament between the two. (Fig. 5) *(Seebacher et al,.1982)*

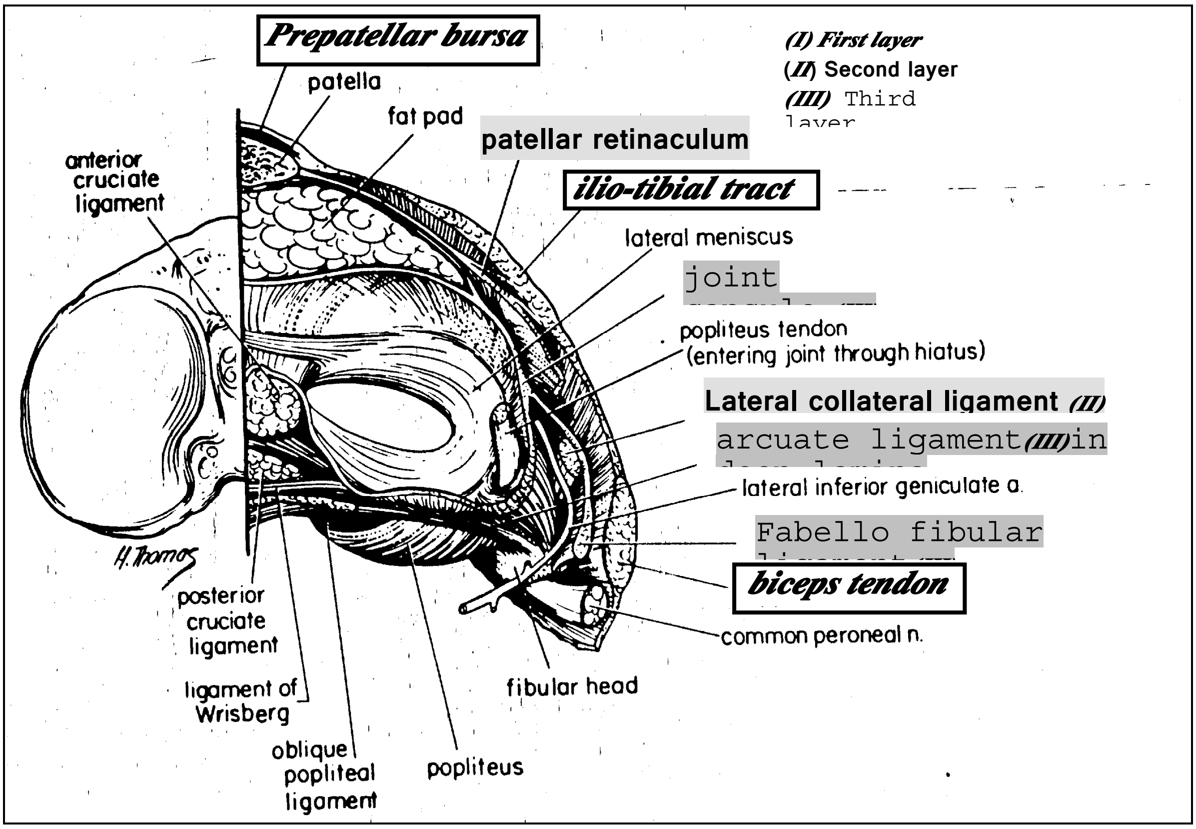

Fig. 5: The layered approach applied to the cross-sectional anatomy of the lateral aspect of the knee. (From Seebacher et al., 1982)

Layer II is formed anteriorly by the quadriceps retinaculum, which is adherent to layer 1 at the edge of the patella. Posteriorly ***layer II*** is incomplete and is best represented as two patellofemoral ligaments. The proximal patellofemoral ligament is joined by terminal fibers of the lateral intermuscular septum. The distal patellofemoral ligament has extensions to the lateral intermuscular septum, fabella, iliotibial tract, lateral meniscus, and tibia. *(Seebacher et al,.1982)*

Layer III is the deepest layer and forms the lateral part of the joint capsule. It attaches directly to the femur proximally and to the tibia distally. The capsular attachment to the outer edge of the lateral meniscus is termed the coronary ligament. The popliteus tendon passes through a hiatus in the coronary ligament to attach to the femur just anterior to the femoral attachment site of the lateral collateral ligament. The "bare," unattached area of the lateral meniscus occurs at this hiatus. Just posterior to the overlying iliotibial tract, the capsule divides into two laminae separated by the inferior geniculate artery, which passes forward in the space between them. The superficial portion of ***layer III*** encompasses the lateral collateral ligament (***layer II***) and terminates at the fabellofibular ligament. The deeper layer of the posterolateral part of the capsule passes along the edge of the lateral meniscus, forming the coronary ligament and the hiatus for passage of the popliteus tendon. This deeper lamina ends posteriorly at the Y-shaped arcuate ligament. The arcuate ligament crosses the popliteus muscle and tendon from the styloid process of the fibula to the femur. *(Seebacher et al,.1982)*

Three anatomic variations of the arcuate and fabellofibular ligaments were described by **Seebacher in 1982:**

(1) The arcuate ligament alone reinforced the posterior capsule in 13 percent of knees.
(2) The fabellofibular ligaments alone reinforced the capsule in 20 percent of knees.
(3) Both of these ligaments reinforced the posterolateral aspect of the capsule in 67 percent of knees. *(Seebacher et al,.1982)*

These variations could be predicted by the presence or absence of a fabella. When the fabella was large, the fabellofibular ligament was present. However, if the fabella or its cartilaginous remnant was absent, the fabellofibular ligament was also absent and only the arcuate ligament was present. Both the arcuate and fabellofibular ligaments insert on the apex of the fibular styloid process.

(Hughston et al,.1976)

The popliteus muscle arises from the posterior surface of the tibia and has insertions into the posterior portion of the lateral meniscus and the femur, deep and anterior to the lateral collateral ligament. The popliteus functions as a dynamic internal rotator of the tibia. In its static role, it restricts posterior translation, varus rotation, and external rotation of the tibia on the femur. There are variations of the attachment of the popliteus muscle to the posterior horn of the lateral meniscus. The popliteus sends firm attachment fibers to the lateral meniscus in a majority of knees, functioning to retract the lateral meniscus during knee flexion.

(Insall et al,.1993)

The tibial origin of the popliteus muscle is broad, and is oriented obliquely so that tension along the tendon is probably transmitted throughout the tibia. This is the only major structure positioned in an oblique fashion, and therefore well suited to prevent external rotation of the tibia. Thus, the popliteus functions both as a static and an active restraint to external rotation, rather than just an active internal rotator of the tibia. *(Insall et al,.1993)*

The blood supply of the cruciate ligaments is primarily derived from the middle genicular artery which arises from the popliteal artery and enters the joint capsule posteriorly at the intercondylar notch. Ligamentous branches of this artery pierce the synovium and arborize to form a network of vessels that envelop both the anterior cruciate ligament and posterior cruciate ligament. The cruciates may also receive blood supply from branches of the inferior genicular artery through connections of these branches with the fat pad and synovium . Within the ligament, the blood vessels are located in the loose connective tissue that is sited between longitudinal fiber bundles. *(Arnoezky , I983)*

Lymphatics accompany most of the small blood vessels, showing similar regional distribution. Compared to the surrounding synovial layer, the amount of vessels in the substance of the ligament is lower. The distribution of blood vessels within the posterior cruciate ligament, is not homogenous. There are three avascular areas within posterior cruciate ligament. Both the fibro cartilaginous entheses of posterior cruciate ligament are devoid of blood vessels, and a third avascular zone is located in the central part of the middle third.

(Petersen and Tillmann, 1999).

The nerve supply of the cruciate ligaments is derived from the posterior articular nerve. The posterior articular nerve, this prominent branch of the posterior tibial never arises at a variable level above the knee or within the popliteal fossa. From this origin, it courses laterally, wrapping around the popliteal vein and artery and descends into the fatty substance of the popliteal plexus. Fibres from this dense plexus penetrate posterior capsule and course through the synovial lining of the cruciate ligaments. *(Wilson and Fowler, 1990).*

Fusiform mechanoreceptor structures which morphologically resembled Golgi tendon organs in anterior and posterior cruciate ligaments were noted, these receptor organs, thought to play a role in proprioceptive reflex arcs, were located on the surface of the ligament in fibrous, fatty, and vascular tissue well beneath the synovial sheath. *(Schueltz et al., 1984).*

Histological study of mechanoreceptors in posterior cruciate ligament from healthy knee, identified Ruffini corpuscles (Pressure receptors),Vaterpicini corpuscles (velocity receptors), free nerve endings (pain receptors), these studies indicate that disruption of the Posterior cruciate ligament alters not only the kinematics of the knee but also the afferent signals to the central nervous system. *(Katonis et al ., 1992)*

Biomechanics

Biomechanical analysis of the function of the posterior cruciate ligament and postcrolatcral structures has added significantly to our understanding of their role in stabilizing the knee. However, the experimental detail of these studies may initially be somewhat confusing. The two most common experimental methods used for biomechanical knee ligament analysis are (1) measurement of the restraining force that develops in individual ligaments during predetermined displacements, and (2) selective ligament cutting studies. These methods provide important information; however, there are significant differences between the two experimental approaches. *(Butler et al.,1980)*

The individual ligament restraining force is assessed in terms of the percent of the total restraining force it provides. By determining the force necessary to produce a predetermined amount of displacement, the relative importance of a certain structure is determined by sectioning that structure and then calculating the difference in the force required to produce the same displacement. The decline in force required is directly correlated with the percentage of stabilizing force contributed by that structure in the direction tested. *(Butler et al.,1985)*

Selective cutting studies attempt to determine knee joint laxity before and after a specific ligament is tran-sected. A force is applied to an intact knee, a specific ligament is cut, and the test is repeated, measuring the change in displacement. This method provides a reliable indication of the effect of a specific ligament injury on joint stability. However, joint laxity is a result of the complex interaction of all ligaments and other secondary stabilizers, and this interaction is altered when a liga ment is cut or injured. Therefore, change in joint laxity is due not only to the loss of the ligament, but also to changes in the interaction and function of the remaining ligaments. *(Noyes et al.,1980)*

Selective cutting studies offer a major advantage, as they directly measure changes in displacement of the knee joint that occur when individual or combined ligaments are sectioned. Additionally, ligament function is determined by measuring changes in motion of the knee in a 90-degree arc of motion. This allows to evaluate abnormalities of motion in a manner similar to that used during clinical testing.

The angle of knee flexion at which clinical laxity testing is most accurate can be determined for each ligament. *(Gollehon et al.,1987)*

Both Gollehon and colleagues in 1987, and Grood and colleagues in 1988, have reported biomechanical analyses of the role of the posterior cruciate ligament and posterolateral structures in knee stability. These studies used the selective cutting testing format to measure changes in rotation and translation following sectioning of these structures in various orders. They presented important information about the relative roles of these ligamentous structures in stabilizing the knee, as well as patterns of instability following injury. The close correlation of data between the two studies is evidence of the accuracy and reproducibility of the methodology.

(Grood et al.,1988)

The critical information is summarized from three points of view. First, for each relevant degree of freedom of the knee (anterior-posterior translation, varus-valgus rotation, internal-external rotation), to review the normal parameters and the effects of isolated and combined sectioning of the posterior cruciate ligament and posterolateral structures. Second, looking at each structure and review the effect of each isolated and combined sectioning pattern on the six degrees of freedom of the knee. Finally, the information is applied to the clinical practice of determining the most accurate examination technique used in evaluating the posterior cruciate ligament and posterolateral structures for injury. *(Grood et al.,1988)*

It is helpful to clarify the anatomic terminology used in the work by Gollehon and colleagues. In an effort to. simplify reporting, they termed the structures of the posterolateral knee the "deep ligament complex. The deep ligament complex includes the popliteus tendon, fabellofibular ligament, and posterolateral capsule. The lateral collateral ligament was considered separately. *(Gollehon et al.,1987)*

Anterior-Posterior Translation with Anterior-Posterior Force:

Isolated section of the posterior cruciate ligament significantly increases posterior translation at all angles of flexion. The absolute amount of translation increases progressively from 0 to 90 degrees of flexion (Fig.6). Isolated section of the lateral collateral or deep ligament complex (arcuate ligament, fabellofibular ligament, popliteal tendon, posterolateral capsule) produces no increase in posterior translation at any angle of flexion. *(Gollehon et al.,1987)*

Combined sections of the lateral collateral ligament and deep ligament complex results in small (approximately 3 mm) but significant increases in posterior translation at all angles of flexion. At 0 and 30 degrees of flexion, the increase in posterior translation produced by combined sections of the lateral collateral ligament and deep ligament complex is similar in magnitude to that produced by isolated section of the posterior cruciate ligament (Fig. 6). Combined sections of the posterior cruciate ligament, deep ligament complex, and lateral collateral ligament results in a significant increase of 20 to 25 mm in posterior translation at all positions of flexion compared with the intact knee or knees in which isolated section is performed (Fig. 6). *(Gollehon et al.,1987)*

Neither isolated nor combined sections of the posterior cruciate ligament and posterolateral structures produce an increase in anterior tibial translation.

Varus-Valgus Rotation with Varus-Valgus Torque:

In the intact knee, the least amount of varus and valgus rotation occurs at full extension. Varus and valgus rotation increases continually with increasing flexion of the knee to 90 degrees (Fig. 7). Isolated section of the anterior or posterior cruciate produces no significant increase in valgus or varus rotation at any angle of knee flexion.

An increase in valgus rotation cannot be produced by isolated or combined sections of the lateral collateral ligament, deep posterolateral structures, or posterior cruciate ligament. *(Gollehon et al.,1987)*

Compared to the intact knee, a small but significant increase (1 to 4 degrees) in varus rotation occurs at all angles of flexion when only the lateral collateral ligament is sectioned. A similar magnitude of increased varus rotation is produced at 90 degrees of flexion when only the deep ligament complex is sectioned. A larger increase (5 to 9)° occurs with combined section of the lateral collateral ligament and deep ligament complex (Fig.7). An even larger increase (14 to 19)° in varus rotation occurs at all angles of flexion when the posterior cruciate ligament is subsequently