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THE ASSESSMENT OF FUNCTION FOLLOWING INTRA-ARTICULAR ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION (12 - 48 MONTHS POST-OPERATIVELY)

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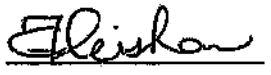
A research report submitted to the Faculty of Health Sciences,
University of Witwatersrand, Johannesburg
in partial fulfilment of the requirements for the
degree of Master of Science in Physiotherapy.

Johannesburg, 1998

DECLARATION

I, CAREN FLEISHMAN, declare this research report to be my own work. It is being submitted in partial fulfillment for the requirements for the degree of Master of Science in Physiotherapy at the University of the Witwatersrand. It has not been submitted before for any degree or examination at this or any other University.



DATED at JOHANNESBURG on this the 2nd day of October 1998.

ABSTRACT

The purpose of this retrospective study was to assess the subjective, objective and functional results of intra-articular anterior cruciate ligament (ACL) reconstructions using the patellar tendon. The subjects of one orthopaedic surgeon were assessed to eliminate surgical variability. Twenty active males, aged 20 - 35 were assessed twelve to forty-eight months post-operatively. Each subject completed a questionnaire and underwent various functional and subjective tests.

Eighteen subjects (90%) were satisfied with the outcome of their operation. Fourteen (70%) complained of intermittent pain or discomfort. Six (30%) complained of some form of post-operative giving way. Nineteen (95%) had returned to sporting activity but most modified their sport or level of participation.

Knee stability was restored post-operatively. Nineteen (95%) had a side-to-side difference of three millimetres (mm) or less on Lachman testing and eighteen (90%) a side-to-side difference of 3mm or less on anterior drawer testing. Thirteen (65%) had a 3mm or less side-to-side difference on KT1000 testing at 20 pounds (lbs) and 14 (70%) a side-to-side difference of 3mm or less on manual maximum testing.

Isokinetic muscle testing revealed persistent quadriceps deficits greater than 20% in seven subjects (35%) and three (15%) had similar hamstring deficits.

Various factors may affect post-operative function. These include the length of rehabilitation, pain, residual quadriceps weakness and restoration of stability.

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S Reubenson
E Slater
H Talbot
R Youngworth

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NOMENCLATURE

ACL = Anterior cruciate ligament

ADL = Activities of daily living

MCL = Medial collateral ligament

PCL = Posterior cruciate ligament

°/s = Degrees per second

The patellar ligament is the central band of the tendon of the quadriceps femoris continued distally from the patella to the tibial tuberosity.

In this text the patellar ligament will be referred to as the patellar tendon as this is an accepted "day-to-day" term and is the terminology used in all the literature reviewed.

1.0 INTRODUCTION

The knee is the largest synovial joint in the body with long lever arms proximal and distal to its centre. It is not surprising that the knee is frequently injured in accidents and athletic contests (Baugher & White, 1985). Injuries involving the anterior cruciate ligament (ACL) are common (Daniel et al, 1994). Most of these injuries occur during participation in sports activities, especially those involving deceleration, twisting, cutting (zig zag movement) and jumping (Daniel et al, 1994). For a competitive athlete, this injury can be career threatening but for the recreational athlete, an ACL deficient knee may require lifestyle and activity adaptations to compensate for the injury (Swenson & Fu, 1993).

Injury to the ACL presents both a diagnostic and treatment dilemma (Steadman & Rodkey, 1993). Many factors have combined to create increased awareness of this injury in the medical community and general population. Sports related factors, including changes in the shoe-turf interface, shoe-floor interface and boot bindings, have combined to increase the incidence of ACL injury. This increased incidence is particularly prevalent in skiing where statistical evidence of a dramatic increase in ACL injury over the past 20 years has been observed (Steadman & Rodkey, 1993).

The accurate diagnosis and treatment of the torn ACL is essential in decreasing the likelihood of a potentially disabling injury. It is important for the practising orthopaedic surgeon to differentiate the requirements of the high-performance athlete from those of recreational athletes (Steadman & Rodkey, 1993).

ACL injuries can occur in contact (direct) or non-contact (indirect) sports. The most common injury in contact sports e.g. soccer, is a knee injury with a valgus load and external rotation (Johnson & Warner, 1993). Non-contact sports e.g. skiing, basketball and gymnastics can result in ACL injuries due to falls, sudden deceleration to change direction or missed dismounts (Johnson & Warner, 1993).

Disruption of the ACL results in abnormal arthrokinematics of the tibiofemoral joint, allowing subluxation of the tibia. This manifests clinically as "giving way". Repeated episodes of instability lead to stretching of muscles and ligaments (secondary restraints), injury to the menisci and deterioration of joint surfaces (Irrgang, 1993). Progressive instability, recurrent pain and degenerative joint changes may result if the injury is left untreated (Irrgang, 1993).

The knee is one of the most frequently injured joints (Johnson & Warner, 1993) seen by the physiotherapist and the ACL is the mo commonly injured major ligament of the knee (Johnson et al, 1984). The diagnosis of ACL injury has increased due to increased awareness and improved diagnostic skills, particularly since the development of the arthroscope.

Patients are often referred for physiotherapy whether they are managed conservatively or operatively. The aim of rehabilitation is to maximise dynamic stability of the knee, allowing the patient to return to activity without having episodes of instability (Irrgang, 1993). There is often no follow-up of these patients after discharge. Thus, there is little long-term information on how the patients are managing during activities of daily living (ADL) and during sports participation (especially in South Africa).

This lack of follow-up has prompted the author to research this topic and assess the outcome of ACL reconstructions. Doctors and physiotherapists need to know the results of the various methods of ACL management so that they can recommend the best possible treatment for their patients. Elite athletes have special needs as there is pressure for them to return to their preferred sport as soon as possible and an accurate prognosis with these athletes is essential.

Research on the ACL abounds and follow-up reports on different surgical techniques are documented. Often the surgeon who performs the operation investigates his own results. In this study, a physiotherapist assessed the results of an orthopaedic surgeon.

Despite a vast amount of literature on the ACL ranging from anatomy, results of different treatment techniques and return to sport of athletes, controversy still exists concerning the most effective treatment, and many authors claim their technique to be the most successful. Different surgeons still have different opinions on how to treat a torn anterior cruciate ligament.

Johnson et al, (1984) presented 58 orthopaedic surgeons with a hypothetical case of an active 20 year old male with an isolated ACL injury to determine the most satisfactory method of treatment. Three different methods were offered:-

1. 60,5% opted for repair with/without augmentation (additional support);
2. 31% favoured a non-operative solution;
3. 8,5% recommended immediate grafting.

Although the percentages might be different if the same orthopaedic surgeons were again canvassed in 1997, all three options would probably still be offered.

Unfortunately direct comparisons of various procedures and techniques is difficult. Lysholm & Gillquist, (1983) stated "Since the beginning of the century, an increasing number of researchers have presented their results of knee surgery. Their methods of evaluation have been almost as numerous".

1.1 Objectives of this study

The following questions are posed in this study :-

1. Subjective outcome :-
   - 1.1 is the subject satisfied with the surgical outcome?
   - 1.2 does the subject think undergoing surgery has been worthwhile?
   - 1.3 is the subject having residual symptoms - pain, quadriceps weakness and giving way?

2. Return to sport :-
   - 2.1 has the subject returned to his preferred sport?
   - 2.2 is he playing the same sport at the same level as at pre-injury?
   - 2.3 is he wearing a brace for sport?

3. Restoration of stability :-
   - 3.1 is there 3mm or less side-to-side difference on Lachman testing and anterior drawer testing?
   - 3.2 is there 3mm or less side-to-side difference on KT1000 testing at 20 lbs and KT1000 manual maximum testing?
   - 3.3 is a pivot shift present?

4. Functional outcome :-
   - 4.1 is the subject coping with the functional demands of his knee?

5. Does physiotherapy affect the outcome of the reconstruction?

The answers to these questions are documented in the discussion.

2.0 LITERATURE REVIEW

2.1 Anatomy of the ACL

The results of surgical reconstruction have improved as the detailed knowledge of the structure and function of the anterior cruciate ligament has evolved (Reiman & Jackson, 1987).

The ACL is an intra-articular but extra-synovial structure running backwards, laterally and slightly upwards from the tibia to the medial aspect of the lateral femoral condyle. It is situated posteriorly in the intercondylar region (Firer, 1982). It averages approximately 4cm in length and 1cm in width (Ellison & Berg, 1985).

The ACL is a composite of individual fascicles that function collectively so that a portion of the ligament is taut in any position of the knee. This constant tension is possible as a result of the different orientations of the individual fascicles on the femur and tibia.

Femoral attachment: The fibres originate on the posteromedial surface of the lateral femoral condyle near the articular surface, in an oval/elliptical area. The posterior portion of the fibres lie parallel to the articular surface of the lateral femoral condyle. This bony origin ranges between 16 - 24 mm in diameter and is located well posterior in the intercondylar notch.

Tibial insertion: The ACL courses obliquely in an anteromedial and distal direction to insert into the proximal tibia. It inserts into a fossa anterior and lateral to the anteromedial tibial spine and not on to the spine directly. The tibial insertion sends variable fibres anteriorly to pass beneath the transverse meniscal ligament. A few fascicles may insert into the anterior horn of the lateral meniscus. The posterior-inserting fibres can also blend with the lateral meniscus (Girgis et al, 1975).

Meniscal attachment: A well marked slip passes to the anterior horn of the lateral meniscus (Girgis et al, 1975) and sometimes to the posterior horn of the lateral meniscus (if the ACL extends posteriorly around the anterior tibial spine). An occasional attachment may pass to the anterior horn of the medial meniscus (Girgis et al, 1975).

2.1.1 Interstitial anatomy:

Two bundles of fascicles are often described arising from:

1) an anteromedial position;
2) a posterolateral position.

There is a continuum between the anteromedial and posterolateral portions, resulting in a portion of the ligament remaining taut at all times. The presence or absence of distinct bundles has been debated extensively.

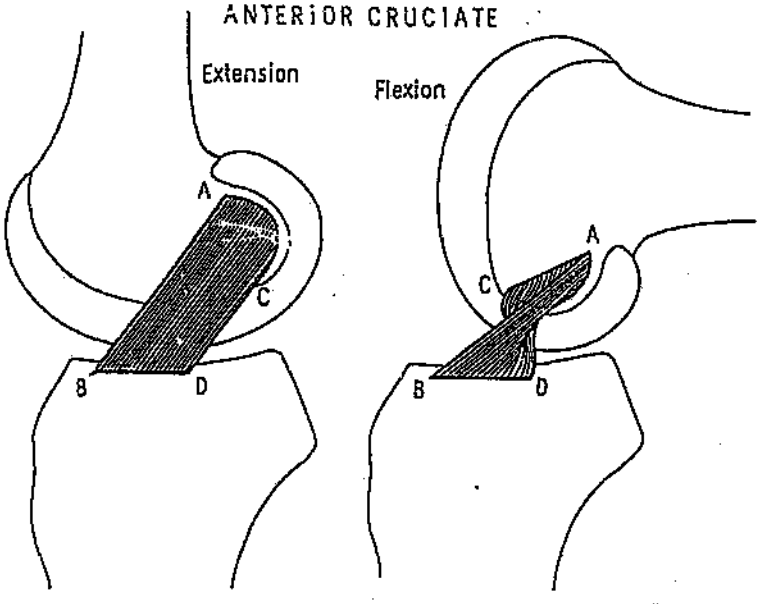


Figure 1 - Schematic drawing representing changes in the shape and tension of the ACL in extension and flexion. In flexion the small medial band (A-B) lengthens and the bulk of the ligament shortens (C-D). (From : Girgis, F.G., Marshall, J.L., Monajem, A.R. The cruciate ligaments of the knee joint: Anatomical, functional and experimental analysis. *Clin. Orthop.*, 106:229, 1975, with permission).

Important concepts of the ACL:

1. Each fibre has a unique point of origin and insertion;
2. The fibres are not parallel and do not have the same length;
3. The fibres are not under the same tension at any one point in time.

In full extension, the ACL takes the form of a broad, flat homogenous structure. In flexion, the ligament twists upon itself about 90° giving the appearance of multiple bundles (Reiman & Jackson, 1987).

2.1.2 Vascularity

The ACL is supplied by:

1) - ligamentous branches of the middle genicular artery:-

The cruciate ligaments are enveloped by a synovial fold originating at the posterior inlet of the intercondylar notch extending to the anterior tibial insertion of the ligament. The synovial fold then joins the synovial tissue of the joint capsule distal to the infrapatellar fat pad. This synovial membrane is richly endowed with vessels that originate predominantly from the ligamentous branches of the middle genicular artery.

2) - terminal branches of the medial and lateral inferior genicular arteries :-

These terminal branches also contribute to this synovial plexus through their connection with the infrapatellar fat pad. The synovial vessels join to form a weblike network of vessels around the ligament ensheathing it entirely. These periligamentous vessels give rise to small connecting branches which penetrate the ligament transversely and anastomose with a network of endoligamentous vessels. The endoligamentous vessels and their supporting connective tissues, are oriented in a longitudinal structure and lie parallel to the collagen bundles within the ligament (Arnoczky, 1983, Arnoczky, 1985).

The ligament-osseous junctions of the cruciate ligaments do not contribute significantly to the vascular scheme of the ligaments themselves (Arnoczky, 1987).

The infrapatellar fat pads play an important role in the vascular scheme of the ACL & posterior cruciate ligament (PCL). The fat pad is supplied by the transverse infrapatellar anastomosis of the medial and lateral inferior genicular arteries (Arnoczky, 1985). The patellar tendon, which is often used in surgery as graft material, receives its blood supply from the infrapatellar fat pad and the retinacular tissues. The retinaculum is supplied by the medial and inferior genicular arteries and the recurrent tibial arteries. The anterior portion

of the patellar tendon is supplied by vessels from the retinaculum throughout its length and the infrapatellar fat pad supplies the posterior portion of the ligament.

2.1.3 Nerve supply

The knee joint is supplied by three main nerves (Tobias & Arnold, 1985) :-

(a) the femoral nerve (via its three branches to the vasti);
(b) the tibial and common peroneal nerves (from the sciatic nerve) send articular branches with corresponding arteries;
(c) the posterior division of the obturator nerve supplies an articular branch.

The origin of the nerve supply to the ACL is thought to be the tibial nerve (Arnoczky, 1985).

2.1.4 Proprioception

The ACL has proprioceptive functions as well as a stretch reflex function. The mechanoreceptors of the knee joint are found in the ACL, posterior cruciate ligament (PCL), medial collateral ligament (MCL), lateral collateral ligament (LCL), menisci, patellar tendon and the infrapatellar fat pad.

Proprioception has been described as a variation in the sense of touch and includes kinaesthesia (joint motion) and joint position (Irrgang, 1993). Proprioception is thought to be important to provide protection, smooth co-ordinated movement and dynamic stabilisation of joints (Irrgang, 1993).

There are four types of mechanoreceptors (Irrgang, 1993):

TYPE 1: have a low threshold for excitation which adapt slowly. They respond at rest and during movement to convey direction, velocity and amplitude.

TYPE 2: have a low threshold for excitation and adapt rapidly. They are responsible for signalling joint acceleration and deceleration.

TYPE 3: have a high threshold for excitation and are non-adapting. They respond at the extremes of motion and may be responsible for mediating the protective reflex arcs. They are found in the musculotendinous junction.

TYPE 4: are free nerve endings that convey pain.

The mechanoreceptors may be damaged during injury to the ACL resulting in abnormal sensory feedback from the knee and altered neuromuscular control. The aim of proprioceptive training is to maximise the use of sensory information mediated by the joint capsule or musculotendinous unit to dynamically stabilize the joint. Repetition is required for proprioceptive training to develop motor control of abnormal joint motion. Conscious effort is initially required to control abnormal joint motion which becomes automatic and subconscious with repetitive training (Irrgang, 1993).

2.2 Biomechanics of the knee joint

The ACL is the primary restraint to anterior displacement of the tibia (Butler et al, 1980). The iliotibial tract and band, medial and lateral capsules and MCL and LCL act as secondary restraints . A primary restraint provides stability during strenuous activities which subjects the knee to large functional forces while a secondary restraint provides back-up to large joint displacements (Butler et al, 1980). The ACL's function is much more than that of a simple check rein. Along with the PCL, the ACL determines the blend of gliding and sliding between the tibia and femur that characterizes normal knee kinematics. As a result, ACL deficiency not only produces episodic instability but consistently altered joint mechanics as well. This alteration may in turn contribute to degenerative changes often seen in patients with long-standing ACL insufficiency. Therefore, the goal of reconstruction should be to restore stability, normal knee kinematics and prevent premature degenerative joint disease (Graf, 1987).

2.2.1 Functional anatomy

Articular cartilage has a low coefficient of friction. It can only effectively be loaded when compressed and does not resist tensile forces very well. The opposite is true of ligaments (Graf, 1987). When the articular cartilage is compressed, the ACL and PCL prevent anterior and posterior displacement of the tibia respectively. The cruciates act as check reins individually but together they define the motion of the knee.

The shape of the lateral and medial femoral condyles is intimately related to the function of the cruciates. The weight-bearing surface of the medial femoral condyle extends further anteriorly than that of lateral femoral condyle. The medial femoral condyle contains an extra annular sector of articular surface that extends nearly to the midline, while the weight-bearing surface of the lateral femoral condyle ends in a depression called the sulcus terminalis. In full extension, the lateral tibial plateau reaches the anterior end of the weight-bearing surface of the lateral femoral condyle and impinges at the sulcus terminalis. The medial femoral condyle with its longer articular surface, : 's additional gliding to occur in the medial compartment. There is an automatic 15° external rotation of the tibia during the terminal 20° of extension. This is termed the "screw-home mecha..ism" (Graf,1987).

Th. ACL is tight in extension. Internal rotation of the tibia at this point would tighten the ligamem further, whereas external rotation would relax the ligament (Arms et al, 1984). Therefore as the knee nears terminal extension and the bulk of the ACL tightens, externally rotating the tibia may relax the ACL enough to allow the last few degrees of extension (Graf, 1987).

The lateral and medial tibial plateaus are also asymmetrical. The tibial plateaus are separated by an intercondylar region which contains two tibial spines - the anteriorly located medial spine and the posteriorly located lateral tibial spine (Danzig et al, 1981). These structures prevent medial or lateral subluxation of the tibia and form a central pivot for internal and external rotation (Graf, 1987).

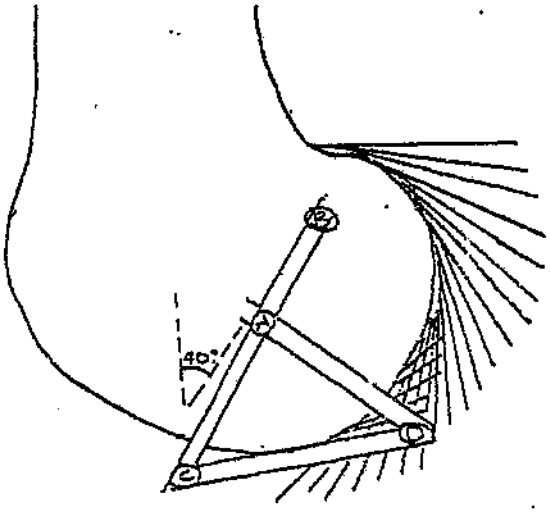
The menisci are important weight-bearing structures and improve congruence between the femoral condyles and tibial plateaus. The medial meniscus helps stabilise the anterior cruciate deficient knee (Graf, 1987).

Both rolling and gliding movements occur between the articular surfaces of the tibia and femur during knee flexion. Rolling occurs as the contact point moves posteriorly on the tibia. If the femoral and tibial contact points are plotted, the femoral points are more widely spaced. Gliding must occur to accommodate the difference. The location of the instant centre of rotation is determined by the position of the knee. This is because the radius of the distal femur which is non-spherical, changes continually (Graf, 1987).

The four bar linkage system will be explained in detail on the following page.

2.2.2 Four bar linkage

A.



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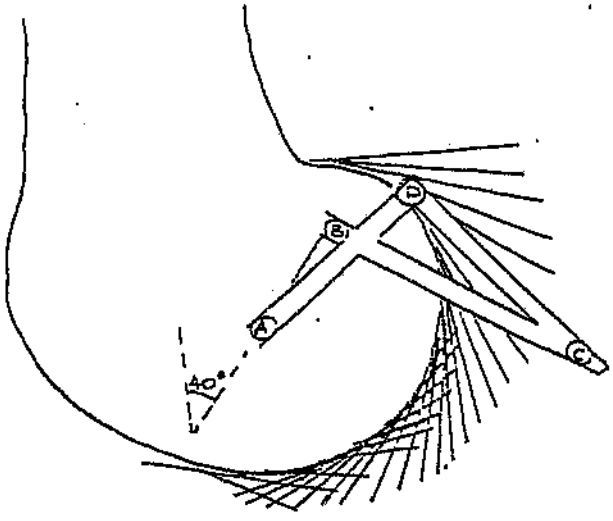

Figure 2.2 - A + B : The four bar linkage model recreates the shape of the femor condyle. (From : Graf, B. 1987 Biomechanics of the ACL. In : Jackson, D.W. & Dre D. Jnr. *The anterior cruciate deficient knee : New concepts in ligament repair.* St Loui C.V. Mosby, p 64, with permission).

The basic principle of flexion and extension can be represented by the mechanism of a crossed four-bar linkage. In this model (Fig. 2.2), four joints are connected by four rigid segments. AD represents the PCL and BC, the ACL. Uncrossed segment AB establishes a fixed distance between the origins of the ACL and PCL and CD a distance between the insertions of the ACL and PCL. If "femoral" segment AB is fixed, lines can be traced along the "tibial" surface of segment CD for varying positions of the linkage. Such a tracing results in a curve similar to the profile of the femoral condyle. This is called the "coupler" envelope curve. The ability to approximate the curve of the femoral condyle with a simple model of the cruciates emphasizes the interrelationship between ligament function and bony anatomy (Graf, 1987).

An important determinant of joint range is the orientation of the segment connecting the cruciate origins in relation to the long axis of the femur. Only when line AB forms an angle of 40° with the long axis of the femur (analogous to the normal roof of the intercondylar notch) will a normal range of motion result. As a result of this orientation, hyperextension is blocked when the ACL lies along the intercondylar roof but allows full flexion (Graf, 1987).

During extension, there is a cut-off point where the crossed four-bar linkage ceases to function effectively. This is the point at which hyperextension occurs (Rosch, 1992). At this stage, the ACL occupies the notch of Grant in the femur and further movement is blocked. The crossed four-bar linkage now becomes a rigid triangle and cannot function any further (Rosch, 1992). If hyperextension were to be forcibly continued, the ACL would rupture.

The crossed four-bar linkage system not only illustrates range of movement but also the normal combination of gliding and sliding between the tibia and femur. During flexion, the femur moves posteriorly on the tibia. For any position of the knee, the point at which AD (PCL) and BC (ACL) cross is the instant centre of rotation. Therefore the centre of rotation moves posteriorly with increasing knee flexion (Graf, 1987).

2.3 Functions of the ACL

Considering the biomechanics, there are five main functions of the ACL related to the four-bar linkage system (Ellison & Berg, 1985):

1. Resists anterior tibial translation on the femur in flexion (provides 86% of the resistance to anterior drawer testing).
2. Prevents hyperextension of the knee.
3. Controls rotatory movements by providing a check to internal axial rotation.
4. Resists valgus and varus stresses throughout the range of flexion by acting as a secondary restraint.
5. Tension in the ACL fine - tunes the "screw-home" stabilization of the joint as it approaches terminal extension.

2.4 Historical overview of ACL surgery

The first reported surgical repair for chronic knee instability was performed in 1885 by Mayo Robson. The first reported reconstruction took place in 1917 when Hey Groves used a proximally based strip of iliotibial band (Burnett & Fowler, 1985).

Various tissues have been used over the years for repairs and reconstructions :-

- in 1918, Alwyn Smith described the use of a distal strip of the iliotibial band to reconstruct the ACL and MCL;
- in 1926, Bennett used a free strip of fascia in an extra-articular reconstruction for the ACL-deficient knee;
- in 1932, Cubbins used the biceps femoris aponeurosis together with the iliotibial band;
- in 1934, it was believed that a medial extra-articular reconstruction alone could provide excellent stability in a chronic ACL-deficient knee to stabilise an unstable knee. This was done alone by reconstructing the medial collateral ligament using free strips of iliotibial band.
- in 1936 and 1939, Campbell described intra-articular routing of the quadriceps tendon, capsule and patellar tendon;
- in 1939, Macey suggested using semitendinosus for reconstruction of the ACL;
- in 1956, semitendinosus was used for an intra-articular dynamic ACL reconstruction;
- in 1959, Lindstrom suggested using a meniscus for ACL reconstruction;
- in 1963, Jones used the central third of the patellar tendon with a wedge of patellar bone for ACL reconstruction;
- in 1967, gracilis was advocated for an intra-articular dynamic ACL reconstruction;
- in 1968, Lam used the medial third of the patellar tendon twisting it 360° to simulate the spiral effects of the normal ACL;
- in 1968, Slocum and Larson described a test to diagnose rotatory instability and a pes anserine transfer to control the instability;

- in 1973, Nicholas described a five-in-one procedure to control antero-medial rotatory instability. This consisted of a total medial menisectomy, posterior and proximal advancement of the femoral attachment of the MCL, distal and forward advancement of the posteromedial capsule, advancement of the posterior part of vastus medialis and a pes anserine transfer.

Ivan Palmer described the "drawer test" in 1938 to demonstrate an increase in anterior translation of the tibia. The Lachman test was described in 1968 as an indicator of anterior tibial translation. MacIntosh and colleagues described the "pivot shift" in the 1970's (Burnett & Fowler, 1985). It signified the extent of knee dysfunction according to the degree of laxity caused by a deficient ACL and secondary ligamentous restraints (Losee,1988). Variations of the pivot shift test were documented by various authors e.g. Slocum & Losee.

The trend in the 1970's was defining and treating specific types of rotatory instabilities in the ACL deficient knee (Burnett & Fowler, 1985). Different donor tissues, as mentioned previously, were again experimented with, the iliotibial band and patellar tendon being the most popular. A combination of intra-articular and extra-articular reconstructions were the subject of experiment, due to the poor results of extra-articular reconstruction alone. Ongoing research has since shown that intra-articular reconstructions alone are as good as a combination of intra-articular and extra-articular reconstructions (Amis and Scammel,1993)

The 1980's may become known as the decade of the prosthetic ACL (Burnett & Fowler, 1987). Synthetic fibres like dacron, teflon, polypropylene and carbon fibres were used. Often synthetic material was intended to act as a "scaffold" on which connective tissue could proliferate and form a neoligament (Arnoczky, 1987). Research into synthetic ligaments is ongoing but long-term results are still being investigated.

The 80's and 90's heralded the eve of arthroscopic assisted ACL surgery. This method has the advantages of:-

1. a smaller sized incision;
2. less disturbance to the extensor mechanism (Wilcox & Jackson, 1987).

"The avoidance of the parapatellar arthrotomy incision and patellar dislocation has resulted in less morbidity, fewer adhesions and less long-term extensor mechanism pain. The patient experiences much less post-operative pain with this method. Post-operative range of motion and quadriceps strength return faster during the early rehabilitation period" (Wilcox & Jackson, 1987).

Technical details such as ligament fixation, tensioning of grafts and isometric placement are still topics of ongoing research. Isometric placement is defined as a position where the femoral and tibial attachments in the joint do not change their length relationship during flexion and extension. This results in stability throughout the range of movement.

Gillquist, (1993) commented that research should determine the reason for poor results of many of the operative techniques, rather than continuing experimentation with new material as grafts. This is a valid comment in light of the fact that 65 methods of ACL reconstruction were documented between 1963 and 1983 (Jensen et al, 1983).

2.5 Mechanisms of ACL injury

The mechanism of injury may be due to intrinsic or extrinsic forces.

2.5.1 Intrinsic forces: These are generated by a sudden change in direction to the side of the injury. The knee is usually extended or hyperextended and the weight-bearing foot is fixed to the ground which forces the tibia into internal rotation and pulls the ACL taut across the medial femoral condyle or intercondylar shelf i.e. sudden deceleration with rotation or a combined valgus and external rotation force which causes injury to the ACL and medial collateral ligament.

2.5.2 Extrinsic forces: An extrinsic force is applied to the knee causing :-

(a) forced hyperextension;
(b) forced valgus.

Kennedy & Fowler, (1971) demonstrated the effect of a knee injury producing a combination of external rotation and abduction. The medial capsular ligament tears first, then the medial collateral ligament and if the force continues, the ACL will also be injured. A blow on the medial side of the knee, causing a varus and internal rotation load will cause similar damage to the lateral ligaments. The ACL can also be involved if the force is strong enough.

An "isolated" ACL injury is generally uncommon although it has been described in the literature. (Youmans, 1978; Feagin & Curl, 1976; Finsterbush et al, 1990). Other authors (Slocum & Larson, 1968; Noyes & Grood, 1976) believe that it cannot be a truly isolated injury. Noyes & Grood (1976) felt it was impossible for the ACL to rupture without some damage being done to the other ligaments. Slocum and Larson, (1968) believe that an "isolated" ACL rupture is a clinical, rather than a pathological diagnosis. Firer (personal communication, 1995) believes that the "isolated" ACL injury occurs macroscopically but not microscopically.

2.5.3 Sport-specific injury mechanisms

The ACL is often injured in sports (contact or non-contact) involving directional changes, e.g. skiing, soccer, rugby and basketball.

SKIING - the knee is often forced into valgus which can injure the MCL and/or ACL with or without medial meniscal involvement.
BASKETBALL - the player jumps up and lands on a fixed foot with a rotated femur causing injury.
RUGBY/SOCCER - a blow. e.g. from a tackle, results in a valgus force which can injure the MCL and ACL with or without medial meniscus involvement. The lateral meniscus can be involved if the force is large enough.

A player who changes direction on a fixed foot resulting in knee rotation can cause an "isolated" ACL injury.

2.6 Treatment of ACL injuries

Treatment of ACL injuries can either be :-

2.6.1 conservative;

2.6.2 operative -

- 2.6.2.1 extra-articular (Arnold, 1985, Carson, 1985);
- 2.6.2.2 combination of both intra- and extra-articular (Carson, 1985; Clancy et al,1982; Hughston & Barrett, 1983; Zarins, 1985);
- 2.6.2.3 intra-articular -
  - i) direct suture repair (Steadman & Rodkey, 1993; Feagin et al, 1992);
  - ii) direct repair augmented with other tissues e.g. semitendinosus (Cross et al, 1993; Engebretsen et al,1990; Sherman et al, 1991);
  - iii) various tissues

The various tissues used for reconstructions include prosthetic ligaments, allografts (freeze dried patellar tendon) and autograft tissues (patellar tendon, hamstrings).

Prosthetic ligaments and allografts will not be discussed in this report, but autograft tissues will be discussed in detail (see page 22).

As this research report assesses the outcome of patellar tendon reconstructions, only patellar tendon reconstructions will be reviewed in detail in the literature review.

The choice of surgical procedures depends on numerous factors, including :-

1. Acute versus chronic injury.
2. Patients age and gender.
3. Activity level.
4. Degree of instability.
5. Future athletic expectations.
6. Present level of activity (Swenson & Fu, 1993).
7. Ligamentous laxity (Firer, personal communication, 1995)

2.6.2.3 Autograft tissues:

Autograft tissues currently being used are the patellar tendon, semitendinosus and gracilis tendons and the iliotibial band or tract (Swenson & Fu, 1993). At present many surgeons consider the central third patellar tendon graft the most popular substitute for reconstruction.

When selecting a particular autograft, factors that should be considered include :-

1. Harvest and insertion of the material.
2. Donor site morbidity.
3. Tissue strength and stiffness.
4. Tensioning and fixation of the graft.
5. Post-operative rehabilitation (Swenson & Fu, 1993).

In 1981, Clancy et al studied the viability and strength of reconstructions in rhesus monkeys, using the medial third of the patellar tendon as the graft material.

At 8 weeks - there was abundant vascularity in and about the tendon graft and paraligamentous and endoligamentous patterns appeared normal. The femoral and tibial vessels had made significant contributions within the respective tunnels for the graft. The midzone of the ligament was relatively hypovascular bu: histological examination showed numerous small vessels.

3 months - proximal and distal revascularization was readily apparent, as was the relatively hypovascular zone in the mid-portion of the ligament.

6 months, 9 months - revascularization remained unchanged. There was a normal appearing paraligamentous and endoligamentous vascular supply (mainly from the posterior synovial fold). Additionally, substantial contributions from the endosteal vessels were seen within the femoral and tibial tunnels.

12 months - no appreciable degeneration of the tendon was evident, the tenocytes were normal and there was no inflammatory reaction.

Tensile testing of the ACL graft (expressed as a per cent of the average strength of the control medial one-third of the patellar tendon) found it to be 53% as strong at 3 months, 52% at 6 months, 81% at 9 months and 81% at 12 months.

Noyes et al, (1984) compared the structural properties of the patellar tendon, semitendinosus tendon, tensor fascia lata, gracilis tendon, distal iliotibial tract and medial or central third of the quadriceps tendon-patellar retinaculum-patellar tendon complex.

This is presented in table form on the next page.

Maximum loads for the human ACL & its replacements

Table 2.1

TISSUE	% OF ACL	MAXIMUM LOAD
ACL (n=6)	100	1725 ±269N
Central Third Bone-Patellar Tendon-Bone (n=7)	168	2900 ±260N
Medial Third Bone-Patellar Tendon-Bone (n=7)	159	2734 ±298N
Semitendinosus (n=11)	70	1216 ±50N
Gracilis (n=17)	49	838 ±30N
Distal Iliotibial Tract (18mm width) (n=10)	44	769 ±99N
Tensor Fascia Lata (16mm width) (n=18)	36	628 ±35N
Quadriceps-Patellar Retinaculum-Patellar Tendon		
Medial (n=7)	21	371 ±46N
Central (n=6)	15	266 ±74N
Lateral (n=7)	14	249 ±54N

The strongest grafts were the bone - patellar tendon - bone specimens, the central third developing 168% of the ACL strength and the medial third 159%. These two were the only two tissues whose maximum loads were greater than those of ligament being replaced.

In 1993, Rougraff et al evaluated the fate of patellar tendon autografts in 23 patients who had undergone ACL reconstruction. Evaluation was by arthroscopy and biopsy between three weeks to 6,5 years post-operatively. Four stages of ligamentization were found after reconstruction :

1. Repopulation: occurred during the first two months. This was seen by a viable three week specimen with increasing fibroblasts and active nuclear morphology;

2. Remodelling: occurred from two months to one year. Fibroblasts increased rapidly and the active nuclear morphology and neovascularity remained increased. More areas of degeneration were seen due to less mature collagen.

3. Maturation: occurred from one to three years. This stage was characterized by a slow decline in the fibroblasts, increased maturation of the collagen matrix and decreased vascularity. The graft is nearly ligamentous.

4. Quiescence: by three years all grafts were ligamentous and did not change significantly thereafter. The graft is less cellular, less vascular and appear similar to ACL controls.

The authors concluded: "Human autogenous patellar tendon grafts are viable as early as three weeks post-operatively and may not go through a necrotic stage. They then progress through a prolonged process of ligamentization that takes as long as three years to complete".

The authors identified the short comings of their study :
1. using biopsies instead of entire ligament specimens;
2. trying to quantify histologic findings;
3. lack of use of autoradiographic techniques to assess fibroblast activity.

In 1993, the strength of the central third patellar tendon graft was investigated by Cooper et al and their results suggest the tendon to be stronger than previously reported (their 15 mm wide bone-patellar tendon-bone composite had an ultimate load of 4389 N compared to Noyes et al, (1984) 2900 N on a 14 mm wide graft). The possible cause of the difference could be the improved clamp design which decreased slippage and decreased the likelihood of stress formation. Twisting the graft 90° increased the strength but twisting

it 180° had no significant effect compared to 90°.

In 1994, Steiner et al compared the tensile properties of hamstring (semitendinosus/gracilis) and patellar tendon reconstructions in 18 pairs of knees. The population ranged from 48 - 79 years which is older than the population used in this report. Four techniques were used for both the hamstrings and patellar tendon reconstructions.

The average maximum load of the intact ACL was 800 ± 469N. Load was defined as the peak load sustained by the graft. The average stiffness for the intact ACL was 66 ± 26N/mm. Stiffness was defined as the slope of the curve in its linear region. Stiffness correlates with clinical grading of the joint - the greater the stiffness, the less the displacement for a given force and the lower the grade of laxity. None of the fixation techniques (semitendinosus/gracilis or patellar tendon) had higher values than the intact ACL (66 + 26N/mm). The stiffest semitendinosus/gracilis graft had less than half the stiffness of the intact ACL while the patellar tendon grafts were notable for their close-to-normal ACL stiffness. Both types of grafts failed most often on the tibial side.

The authors recognized the limitations of their study :

1. donor age - the mechanical properties of connective tissue deteriorate with age. Younger donors would probably have had higher stiffness and strength measurements;
2. the static nature of the tests;
3. potential variability in healing between different grafts.

In 1995, Howell et al investigated revascularization of the human ACL graft (using gracilis and semitendinosus) in the first two years of implantation. Forty five unimpinged grafts were assessed. They found that the unimpinged graft acquired no discernible blood supply during the two years of implantation but the periligamentous soft tissues were richly vascularised and covered the graft by one month.

The patellar tendon has been advocated by many authors (Butler et al, 1980; Clancy et al, 1981; Kaplan et al, 1991; Howe et al, 1991; etc) as the superior substitute from a

biomechanical point of view due to its durability (Sandberg & Balkfors, 1988) and revascularisation properties (Drez et al, 1991).

Franke, (1985) states the patellar tendon to be advantageous because :-

1. it has a great tensile strength;
2 no additional incision is necessary for removal;
3. there is always sufficient length;
4. bone portions improve integration which can be promoted by synovial wrapping;
5. prevention of synovitis.

2.7 Literature review on patellar tendon reconstructions

2.7.1 Comments on reviewing the literature

Volumes have been written on the ACL. Assessing this information is difficult due to the wide range of techniques and assessments thereof. There seems to be no standard evaluation - authors often devise their own assessment or scoring scale or modify ones already being used (e.g. Lysholm and Gillquist, 1983; Tegner and Lysholm, 1985).

Many of the articles reviewed had several of the following faults :

i) lack of standardised technique in follow-up evaluation; e.g. Howe et al, (1991); Aglietti et al, (1992); Glasgow et al, (1993);

ii) differences in patient populations - including gender, age; e.g. Johnson et al, (1984); Shelbourne et al, (1990);

iii) using subjects that place different demands on their knee (e.g. athlete versus sedentary, desk worker versus labourer); e.g. Harter et al, (1988);

iv) length of time between injury and reconstruction; e.g. Johnson et al, (1984); Elmquist et al, (1988); O'Brien et al, (1991);

v) status of knee at time of surgery - many authors include patients who have had previous/additional surgery (including reconstructions) on the knee; e.g. Johnson et al, (1984); Howe et al, (1991);

vi) varying indications for surgery resulting in a mixed population; e.g. Elmquist et al, (1988);

vii) actual injury and varying surgical technique resulting in a mixed population; e.g. Glasgow et al, (1993); O'Brien et al, (1991);

viii) more than one surgeon performing the surgery; e.g. Tibone & Antich, (1988); Johnson et al, (1984);

ix) more than one person assessing the outcome without establishing intertester reliability; e.g. Howe et al, (1991); Buss et al, (1993);

x) small sample size; e.g. Tibone & Antich, (1988); Rosenberg et al, (1992);

xi) biasing of results due to patients being lost to follow-up; e.g. Johnson, (1984);

Bartlett & Crowe, (1984); O'Brien et al, (1991); Bach et al, (1994);

xii) different time intervals between surgery to re-assessment i.e. difference in length of follow-up period; e.g. (Wilk et al, (1994) six months and less; Johnson et al, (1984) five to ten year follow-up;

xiii) changing parameters to improve results e.g. changing acceptable side-to-side Lachman differences from 3mm to 4mm (or 5mm); e.g. Howe et al, (1991); Aglietti et al, (1992); Bach et al, (1994);

xiv) lack of detailed information e.g. additional techniques performed at surgery with no adequate reasons given; e.g. Howe et al, (1991); Buss et al, (1993); Elmquist et al, (1988);

xv) in the clinical setting, a totally homogenous population is impossible to attain resulting in variability. These variables affect the final conclusions and results of the studies;

xvi) bilateral injuries in some patients, the other knee cannot act as its own "control"; e.g. Johnson et al, (1984); O'Brien et al, (1991) and Buss et al, (1993);

xvii) differences in post-operative rehabilitation protocols; e.g. Elmquist et al, (1988); Howe et al, (1991); Shelbourne et al, (1990).

As Johnson, (1984) stated: "The lack of a uniform, standardized system for grading and reporting results makes interpretation of the outcomes presented in these studies difficult. In addition, biases are introduced into each study by the number of patients lost to follow-up evaluation. Assessing which portion of a particular treatment protocol has had the most significant contribution to an apparently successful outcome can be difficult, as each individual treatment regimen involves such a large number of variables aside from the type of surgical procedure and the type of graft material used."

A precisely similar opinion was formed by the present author after reviewing a large number of articles on this subject.

In light of the fact that the present study is concerned with intra-articular reconstruction involving the patellar tendon, it was decided that a more detailed review of this procedure

should be undertaken.

For purposes of easy comparison, all figures were converted to percentages (including studies with small samples e.g. O'Brien et al, (1991).

The following factors were considered in critically reviewing the literature pertaining to reconstructions using the patellar tendon:

- subjective results;
- objective results;
- functional results.

2.7.2. Subjective results of patellar tendon reconstructions

In 1970, Jones reported on 46 patients who had undergone ACL reconstructions using the technique he described in 1963. Average follow-up time was 110 weeks and the ages ranged from 14 - 43 years.

Subjectively: Pain was present in 15,2% of patients (2 significant, 5 occasional) and 20% of patients had occasional swelling.

Comment: Intervals between injury and surgery ranged from one week to nine years which is a large time interval. Some patients had additional procedures performed besides their reconstruction.

Johnson et al, (1984) reported on a five to ten year follow-up of 87 patients where the medial third of the patellar tendon was used.

Subjectively: Seven per cent of the patients were very satisfied as their knees had returned to normal. Sixty four per cent were satisfied as their knee had improved but was not normal. Insufficient improvement in their knees resulted in 19,8% of patients being dissatisfied; 4,6% were dissatisfied as there was no change and 4,6% found their knee had

worsened. One patient was not rated using this system. No reason for this was given. Thus, 71% were satisfied with their results and 29% were dissatisfied.

Comment: In Johnson et al's study, seven different surgeons performed the original reconstruction resulting in surgical variability. Only one surgeon performed the follow-up evaluation. Laxity measurements were determined using an instrument designed by the authors. As this instrument is not freely available to other surgeons, reproducibility is difficult and comparisons between studies would be difficult to make. Once again, many patients were lost to follow-up.

Bartlett & Crowe, (1984) studied the results of 170 reconstructions performed between 1975 and 1988. Follow-up averaged 31 months (range 24 - 87 months). Eighty per cent were males and average age was 24 years. Average duration of pre-operative symptoms were 23 months.

Subjectively: Seventy five per cent of patients rated their knee as good, 22% improved and 3% the same or worse. Fourteen per cent experienced episodes of giving way. Workers' Compensation patients showed a poor subjective response to surgery. Only 31% had good results and 54% complained of giving way.

Comment: In Bartlett & Crowe's study, one surgeon performed the surgery eliminating surgical variability and one surgeon performed the follow-up evaluation. This reduced intertester variability.

Elmquist et al, (1988) reported on 29 patients who had undergone ACL reconstruction using the quadriceps-patellar tendon. Different angles of immobilisation were used post-operatively and different modes of early training. The average follow-up was 28 months. The authors did not comment on any subjective parameters, and only clinical results were assessed. (see page 42, Elmquist objective results).

Comment: The duration of symptoms ranged from seven months to 185 months. Of the 29 patients, 14 had had previous surgical procedures before the reconstruction. Twelve patients had additional pes anserine transfers at the time of reconstruction. All these previous surgical procedures and additional transfers could affect the outcome of the reconstruction and patient satisfaction.

Sandberg & Balkfors, (1988) studied the durability of reconstructions using the medial third of the patellar tendon in 30 patients (22 male, 8 female). Ages ranged from 17 - 41. Patients were evaluated twice - the average follow-up was 21 months and average late follow-up 57 months.

Subjectively: Symptoms did not change with time. Three patients still complained of giving way.

Comments: Two-thirds of patients had undergone previous surgery before their reconstruction. This could affect their final results. Sandberg & Balkfors did not give much detail on their subjective symptoms.

Tibone & Antich, (1988) studied 11 patients two years after patellar tendon reconstruction (with lateral augmentation). Five different surgeons performed the technique on the ten men and one woman.

Subjectively: The knee was described as normal by 27,3% of patients while 72,7% described their knee as "improved". The patients were asked to give a numerical value to the condition of their knee pre-operatively and at follow-up. The sample rated their reconstructed knees at 82,7% of pre-injury level compared to 52,75% pre-operatively. Eighty two per cent evaluated their surgical result as "excellent"; 9% as good and 9% as fair.

Comment: Only 11 patients were evaluated at follow-up resulting in a small sample. Five surgeons performed the surgery resulting in surgical variability. Lateral augmentation was

performed in addition to the ACL reconstruction.

Shelbourne & co-workers, (1990) followed up 140 athletes over two to seven years, aged between 15 - 42 years. All were treated with bone-patellar tendon-bone reconstruction within eight weeks post-injury followed by early motion.

Subjectively: Subjective parameters were not documented in detail in the study. Ninety three per cent had not had a feeling or incidence of instability since the reconstruction. Of the nine patients who scored less than 20 on the stability section, six felt their knee might give way if pushed hard enough and only three with a positive pivot shift had an episode of giving way. A modified subjective assessment (originally developed by Noyes) was used. The average score of the reconstructed group was 92,7 points compared to 93,5 of the "normal" knee group.

Comment: Variability was eliminated in this study by only using one method of surgery and only one surgeon performing the surgery. Follow-up varied between two to seven years and as usual in ACL studies, most patients were men (107 males, 48 females). An acute injury was defined as being diagnosed within the first eight weeks post-injury without return to usual activities. It was not documented whether patients with additional injuries (ligamentous or mensical) were included in the study.

Shelbourne & Nitz, (1990) developed an accelerated rehabilitation programme to overcome many of the complications of ACL reconstructions (knee stiffness, limited extension, delay in strength recovery and anterior knee pain). Three hundred and eighty five patients were included in the study of which 138 followed the conventional rehabilitation (Group A) and 247 the accelerated (Group B) programme.

Subjectively: A modified Noyes' knee rating scale was used. Overall activity level (walking, running, stairs, jumping and twisting) accounted for 50 points (of the 100). The remaining 50 points were assigned to pain, stability and swelling. The questionnaire was also administered to 140 competitive athletes with normal knees to act as controls. There

was only a few points difference in the results as perceived by the patients in both rehabilitation groups. Ninety per cent of Group A rated their stability as 20 points out of a possible 20 points and 98% of Group B. The subjective ratings of the athletes with normal knees are in the same range as the reconstructed knees.

Comments: One surgeon performed the surgery. Two rehabilitation protocols were used during the study to see the effect of the different protocols. Range of follow-up varied from 4 - 5 years for Group A and 12 months to 30 months for Group B. As usual, some patients were lost to follow-up during the course of the study.

Shelbourne et al, (1991), in a different series, reported on the effect of timing on reconstruction and rehabilitation in 169 patients who had undergone bone-patellar tendon-bond reconstructions. Surgery was performed within 8 weeks post-injury.

Subjectively: No comments on subjective results were reported.

Comment: The obvious weakness of the study is that no subjective results were documented. One surgeon performed all the reconstructions, reducing intertester variability. Two different rehabilitation protocols were used - the conventional programme in the earlier years and the accelerated programme later on in the study.

Howe et al, (1991) assessed 83 young, active patients in a ten year follow-up. The medial third of the patellar tendon and its extension into the quadriceps tendon was used as a graft, but 35 patients also had a pes anserine transfer. No reasons were given for the additional procedure.

Subjectively: Ninety two per cent of patients were satisfied with their result; 5% were somewhat disappointed and 4% were unsatisfied. Eight per cent were discontent due to residual pain and/or stiffness and 5% of these qualified as failures. Seven per cent had significant pain at follow-up compared to 42% pre-reconstruction. Five per cent had episodes of giving way.

Comment: The quadriceps-patellar tendon technique was used in Howe et al's study. Their rehabilitation protocol changed from the late 70's to the protocol used in the 80's. Additional procedures were performed on many patients including 34 pes anserine transfers and one MCL and posterior oblique ligament reconstruction. Again, patients were lost to follow-up and some interviewed telephonically only. The authors also designed their own subjective questionnaire.

O'Brien et al, (1991) studied the results of 79 patients (80 knees) where the central third of the patellar tendon was used (58 males, 21 females). Forty-eight patients (60%) had additional augmentation using the iliotibial band.

Subjectively: Ninety three per cent were very satisfied/satisfied with he surgery. Seven per cent were dissatisfied, usually due to persistent anterior knee pain. Ninety five per cent of patients no longer complained of giving way while 37% of patients complained of patellar pain.

Comment: The authors did not comment on how many surgeons performed the surgery. One surgeon performed all the physical examinations, another did all KT1000 measurements and another evaluated the radiographs. This reduces intertester variability. The incidence of patellar pain is relatively high (37%). This may be due to six weeks of immobilisation in a cylinder cast post-operatively. Sixty per cent of patients had additional augmentation which could affect the final outcome, although the authors found no detectable effect on their study.

Aglietti & co-workers, (1992) studied 69 patients three to five years after a bone-patellar tendon-bone reconstruction. The Italian Knee Surgery Club Rating Scale was used (50 points for subjective parameters and 50 points for objective parameters).

Subjectively: The average knee score improved from 63 points pre-operatively to 92 points post-operatively. There were 75% excellent results, 19% good and 6% fair results. Pain was present in 5% of patients at follow-up during recreational activities and 9% with

vigorous activities. One per cent of patients complained of giving way during recreational and vigorous activities. Thirty two per cent did not feel a strength difference between the two knees; 54% felt the operated knee was slightly weaker; 12% felt it was definitely weaker and 3% felt the result to be a failure.

Comment: A single examiner performed the follow-up evaluation but the authors do not state how many surgeons performed the reconstructions. The interval between injury and reconstruction varied from one month to 240 months (i.e. 20 years) which is a large range. Patients who had undergone previous surgery were included - 17% medial menisectomies, 3% failed ACL repairs and 1,4% MCL repairs. At the time of reconstruction, various procedures besides menisectomies were performed simultaneously, e.g. an anterolateral tenodesis was used in the first 16 cases and retensioning of the MCL in 4,3%. These factors could have affected the final outcome of their study.

Rosenberg et al, (1992) evaluated the extensor mechanism function in ten patients after they had an ACL reconstruction using the central third of the patellar tendon.

Subjectively: All ten patients were satisfied with their surgical outcome and considered their knee stable (although two had occasional giving way when fatigued after exercise). Eighty per cent had difficulties with stairs. Ten per cent described a popping or grating sensation. Forty per cent described occasional swelling related to activities. Eighty per cent had difficulty kneeling and 20% had difficulty fully extending their knee. Sixty per cent considered the involved leg to be weaker than the opposite side and 50% noticed the operated leg fatigued quicker than the opposite side.

Comment: Rosenberg et al's sample size was small (n=10). This may not be representative of the group as a whole. There were more women than men (six women and four men). This selection of gender is unusual in ACL research as there are normally more men than women in the studies. Timing of surgery varied between two months to 66 months post-injury (i.e. 5½ years). Eighty per cent also had an iliotibial band tenodesis. They concluded that the additional procedure did not affect the results since the two patients who

did not have an iliotibial band tenodesis did not differ significantly from the remaining patients.

Buss et al, (1993) followed up 68 knees using patellar ligament grafts (but ten had augmentation using a strip of iliotibial band). Ten patients were examined by other surgeons other than the two authors. Sixty-seven of the patients responded to the questionnaire.

Subjectively: One reported giving way. Four per cent of the patients rated their knee as excellent (very satisfied with no pain); 54% as good (satisfied, no limitations in activities and had occasional, mild pain); 4% fair (moderate pain, some restrictions in activities and reservations about the success of the procedure) and one as poor (recurrent instability). Almost all of the patients (98,5%) thought the operation was successful and would have it again but 1,5% was dissatisfied and would not do so again.

Comment: In Buss et al study's, 68 knees were examined in 67 patients - thus one patient had surgery on bilateral knees. This excludes the uninjured knee being used as the normal/control knee. Ten patients were examined by different surgeons rather than the authors, resulting in possible intertester variability. Sixty-eight knees had previous procedures (diagnostic arthroscopy and/or menisectomies) but none had previous reconstructions or any form of instability. Ten patients also had additional iliotibial band augmentation in the earlier part of their study and were still included in the results.

Glasgow et al, (1993) evaluated the effect of early versus late return to vigorous activities on the outcome of ACL reconstructions. Sixty four patients were reviewed an average of 46 months post-operatively and divided into two groups - 34 patients who returned to sport two to six months post-reconstruction (Group A) and 33 patients who returned to sport seven to 14 months post-reconstruction (Group B).

Subjectively: There was no significant difference between Group A and B on subjective assessment of pain, swelling and giving way. A modified Cincinnati Knee Rating Scale was

used to subjectively assess symptoms (44,3 out of 50 for Group A and 45,2 out of 50 for Group B) and function (46,9 out of 50 for Group A and 47,6 out of 50 for Group B) which were not significantly different.

Comment: Only one examiner performed the subjective evaluation. Patients who had undergone additional procedures were included in the study. Exclusion criteria of the study resulted in 122 patients being excluded.

Bach et al, (1994) evaluated the outcome of the middle third of the patellar tendon in 62 patients, followed up a minimum of two years post-operatively (range 27 - 51 months).

Subjectively: Ninety five per cent would recommend the procedure or undergo the procedure again. Five per cent would not undergo the procedure again due to knee flexion contractures.

Patient satisfaction was rated on a scale of one to four (one = completely satisfied, two = mostly satisfied, three = somewhat satisfied and four = dissatisfied). The mean value was 1,5 for this group. Six patients were somewhat satisfied of which three had knee flexion contractures. The one patient who was dissatisfied with his result had re-torn his medial meniscal repair, had a stable knee and refused recommended surgery yet indicated that he would recommend the procedure to others.

Comment: Only one surgeon performed the reconstruction and another the follow-up evaluation. The interval from injury to reconstruction ranged from 0,1 months to 156 months (13 years). This large time span for knees reconstructed 13 years post-injury would affect the status of the knees being compared i.e. acute versus chronic reconstructions with involvement of the secondary restraints. Forty per cent underwent previous surgical procedures on the affected knee before their reconstruction. Five even had two previous procedures, and one patient three previous procedures. These previous procedures could affect the final outcome.

Wilk et al, (1994) assessed 50 patients who had undergone ACL reconstruction. Seventy eight per cent were six months post-surgery; 10% were less than six months post-surgery and 12% greater than six months. Ages ranged from 15 - 52 years, of which 51% were under the age of 51 years.

Subjectively: Knee scores revealed an overall rating of 86 points (out of 100), ranging from 65 - 100. Twenty per cent had no knee pain; 52% occasional pain with strenuous activities; 10% pain with moderate work or sports and 18% with ADL. Sixty three per cent had no swelling; 34% occasional swelling with heavy work and 20% with moderate loads. Seventy seven per cent reported no incidence of giving way and 23% reported giving way with strenuous activities. Twenty four per cent complained of stiffness.

Comment: Wilk et al reported an inverse relationship between patient's age and self-assessed knee function - as age increased the subjective knee score decreased. Twelve per cent of patients were assessed more than six months post-operatively but the authors do not state the time interval longer than six months. All their results must be considered to be short term - as most patients were ± 6 months post-reconstruction long-term results may differ with increasing time. The authors do not comment on how many surgeons performed the reconstruction or re-assessment.

2.7.3 Objective results of patellar tendon reconstructions

In Jones' study (1970), (see page 30) of 46 knees, one had quadriceps weakness, two had MCL instability and three had an abnormal gait. (Average follow-up was 110 weeks). Slight quadriceps atrophy was present in 28,3% of patients and marked atrophy was present in 19,6%.

Anterior drawer: (See 3.5.3.2 page 76). Sixty three per cent of patients had a positive anterior drawer test at 90° flexion, but none had instability at 180°.

Range of movement	Percentage of patients
35° - 180°	32,4%
45° - 180°	21,7%
55° - 180°	10,9%
65° - 180°	8,7%
80° - 180°	8,7%
90° - 180°	8,7%
45° - 178°	2,17%
60° - 175°	2,17%
80° - 175°	2,17%
100° - 178°	2,17%

Comment: As this was one of the earliest reports, the results are discussed very broadly and not in detail. No reasons are given for the huge variation in range of movement. It must be remembered that this investigation was done in the 1960's when objective instruments e.g. Cybex isokinetic dynamometer and KT1000 arthrometer were not yet utilised. Jones' recording of range is also unusual as the norm is to use O° (i.e. full extension) to approximately 130° - 140° flexion. The knee cannot bend 180°. He does not explain why he recorded this way and/or what it actually means.

Johnson et al, (1984) (see page 30) in their investigation of 87 patients five to ten years after the medial third patellar tendon reconstruction found the following objective results:

Effusion: Fifteen per cent had a trace of an effusion; 3,4% had a mild effusion; 1,5% a moderate effusion and 80,5% had no effusion.
Tenderness: This was felt at the following sites - patellar (18,4%); patellar tendon (3,4%); medial joint line (2,3%) and lateral joint line (1,5%).

Patellar Mobility: The patella was subluxed laterally with the knee flexed 20° - 30° to determine mobility and compared to the opposite knee. Seven patients were excluded due to bilateral ACL injuries. Of the 80 patients - 41,3% had equal and normal mobility; 5% had equal but excessive mobility; 12,5% had more mobility on the reconstructed side while 41,3% had less mobility on the operated knee. Patellar mobility did not increase the incidence of poor functional results.

Crepitus: On testing active range of movement, 33,3% had no subpatellar crepitus; 49,4% had mild crepitus (of which 13,8% patients had it bilaterally). Dramatic crepitus was present in 16,1% of patients and it was undeterminable in 1,2% of patients due to pain. Mild crepitus was not associated with a poor functional result, but marked crepitus was.

Thigh Atrophy: Atrophy was present in 62,1% of patients of which 34,5% had 1cm or less and none had more than 3cm.

ACL Laxity: Fifty-nine patients were tested on an instrument designed by the authors.

(a) Anterior drawer: - a mean of 5,4mm was recorded on reconstructed knees and 3,2mm on the control knees.

(b) Lachman: - (see 3.5.3.1 page 74) a mean of 6,8mm was recorded on reconstructed knees and 4,8mm on controls.

More patients with less anteroposterior motion subjectively rated their function as good or excellent compared to those with poor or fair results.

The quality of the end point of the Lachman and anterior drawer tests was evaluated as hard or soft. Patients with hard end points had significantly less clinical laxity than those with soft end points. They found the presence of a firm end point during the Lachman test to be a better predictor of good functional results than during an anterior drawer.

Pivot Shift: (see 3.5.4 page 78). This was negative in 67,8% patients; mildly positive in 17,2%; moderate to markedly positive in 9,2%; 1,2% patients had a positive pivot shift on the opposite side and was indeterminate in 4,6% patients. The presence of a mildly positive pivot shift was not associated with an increase in subjective poor results but a moderate or markedly positive pivot shift was definitely associated with worse results.

Range of Motion: Loss of extension was present in 67,9% of patients and loss of flexion in 76,5% of patients when compared to the opposite knee. Loss of movement was greater in the unsatisfactory group than in the satisfactory group. Two patients required a manipulation under anaesthetic to regain motion.

Significant degenerative changes (large osteophytes, joint space narrowing, sclerosis, cyst formation and attrition) were compared with functional recovery. Patients with excellent results had a lower frequency of these changes than patients with good results. Patients with good results had a lower frequency of these changes than patients with fair results but not than those with poor results. There was no statistical difference between patients with fair results and poor results regarding degenerative changes.

Comments: Johnson et al's study is well documented and the authors comment on various objective parameters in detail. It would be easier to compare results to other studies if both the number of their patients and percentages are stated for each parameter. KT1000 testing was not performed, neither was isokinetic testing.

Bartlett & Crowe (1984) (see page 31) did not comment on objective results in detail. The only result reported on was the pivot shift which was negative in 97% of patients.

In 1988 Elmquist & co-workers (see page 31) studied 29 patients who had undergone a reconstruction using a quadriceps-patellar tendon graft. Patients were followed for 28 months and aged between 16 - 37. Twelve patients had a pes anserine transfer as well, but no reasons were given why. The rehabilitation was divided into four different groups but the results were not statistically significant, therefore the results were presented together.

Range of movement: Showed a mean decrease of 5,5° extension (range 0° - 10°) compared to the opposite side and a mean decrease of 6,4° flexion (range 0° - 20°).
Anterior Laxity: There was a marked improvement of stability at follow-up.
Training improved the Lachman test in 76,5% of patients and in 50% of patients undergoing resistance training. Fifty nine per cent improved their anterior drawer test with isokinetic

training as did 75% with resistance training.

Pivot Shift: Ninety three per cent had a negative pivot shift while 7% had a positive pivot shift.

Isokinetic measurements: (see 3.5.10 page 84). The values of the injured leg were significantly lower than the uninjured leg pre-operatively and at follow-up. There were no significant differences between 30°/s, 90°/s and 180°/s pre-operatively compared to values at follow-up.

Comment: The authors did not comment in much detail. KT1000 testing and thigh atrophy received no analysis.

Sandberg & Balkfors, (1988) (see page 32) studied the durability of reconstruction using the medial third of the patellar tendon in 30 patients. Ages ranged from 17 - 41. Patients were followed-up twice, at two years and then five years post-reconstruction. The results published were not discussed in detail. There was a reduction of instability after surgery which remained unchanged over the years. After five years the anterior drawer test was still positive in 70% patients and 86,6% were positive on Lachman testing. The test for lateral rotatory instability remained positive in 6,6%. Subjective symptoms and function did not change with time. Ten per cent of patients still complained of episodes of giving way.

Comment: The incidence of their positive Lachman and anterior drawer values is high. Even a small difference between the end point positions in the Lachman test was regarded as positive and indicated instability to the authors (as opposed to the commonly used and accepted 3mm side-to-side difference). The anterior drawer was measured using a graded caliper designed to fit the knee in 90° flexion and was accurate to within 1mm according to the authors. The results and discussion of this study were not detailed enough. Function was only measured according to the Lysholm score (Lysholm & Gillquist developed a knee scoring scale for follow-up evaluation which emphasised symptoms of instability). Thigh atrophy, range of movement, KT1000 measurements, crepitus and the patellofemoral joint were not analysed. Isokinetic testing was not performed in this study.

Tibone & Antich, (1988) (see page 32) studied 11 patients two years after ACL reconstruction (using patellar tendon,laterally augmented with an iliotibial tranfer). The average age of the ten men and one woman was 25,5 years (range 18 - 45). Five different surgeons performed the reconstruction using a similar technique.

Palpation: Medial joint line tenderness was present in 27,3% of patients; 9% had lateral joint line tenderness and 18% had tenderness of the pateliofemoral joint.
Crepitus: Patellofemoral crepitus was present in 27,3% of patients on active extension.
Effusion: No patients had an effusion.

Thigh atrophy:

Measurement	Deficit	Percentage of Patients
20cm proximal to patella	3,5cm 1,5cm	9% 18,2%
5cm proximal to patella	2cm 1,5cm 1cm	9% 9% 36,4%
15cm distal to patella	2cm -1,5cm	27,3% 9%

A negative value indicates the operated leg to have a larger girth than the unoperated leg.

Range of movement:

Limitation of Movement	Percentage of Patients
5° of flexion	45,5%
10°	27,3%
15°	18,2%
20°	9%
Full extension	27,3%
5° of extension	54,18%
10°	9%
15°	9%

Laxity: Nine per cent had a 2 + (5-10mm) anterior drawer in neutral and 27,3% had 1 + (0-5mm) straight anterior instability on anterior drawer testing. On Lachman testing 45,5% of patients had a 0-5mm of movement (1+). No patients had medial instability in full extension or 30° flexion, nor did any have lateral instability in full extension. Nine per cent of patients had 1 + (0,5mm) lateral instability at 30° flexion.

Pivot Shift: No patient had a positive pivot shift.

Muscle Strength: Isokinetic quadriceps strength was 83% of the opposite leg at 60°/s; 86% at 180°/s and 87% at 300°/s. All these decreases were statistically significant. Hamstring strength at 180°/s was 102% and 98% at 300°/s.

KT1000: (see 3.5.5 page 81). This was tested on the KT1000 arthrometer at 15lbs, 20lbs, manual passive displacement and maximal active displacement. During manual maximal testing, there was significantly greater excursion on the operated side (7,2mm) compared to the opposite side (5,2mm). Only 9% of patients had greater than 3mm side-to-side difference on the other tests.

Comment: These authors commented in detail on most of the objective parameters. The small sample size is the most obvious weakness of their study.

Shelbourne et al, (1990) (see page 33) followed up 140 athletes over two to seven years (ages 15 - 42). All were treated with bone-patellar tendon-bone reconstruction followed by early motion with emphasis on full extension. The following results were found :
KT1000: Showed a mean difference of 1,3mm between the injured and uninjured knee at a 20lb force.
Lachman: A firm end point was present in 97,9% of patients.
Muscle Strength: A Cybex test at two years showed a mean quadriceps strength of 90% and a mean hamstring strength of 98%. There was no significant difference between the results at three different speeds (60°/s, 180°/s and 240°/s).
Range of Movement: Two per cent of patients underwent surgical manipulation to restore full flexion and 15% underwent scar resection for lack of full extension and/or knee pain with soft tissue crepitation. Lack of extension ranged from 0° - 10° compared to the opposite knee with an average loss of 4°.

Comment: Various objective measurements were made in this study e.g. Lachman, Cybex, range of motion but the anterior drawer test was not utilised. Although the anterior drawer is less reliable than the Lachman test, it still is an indicator of ACL laxity and should be tested. The pivot shift, KT1000 and patellofemoral joint were also not assessed. Only patients undergoing reconstruction and/or menisectomy were included in Shelbourne et al's study. Only one surgeon performed the surgery. The rehabilitation programme evolved over the course of the study to one that emphasized early movement, full extension and early full weight bearing. Rehabilitation variability was therefore introduced, although their results improved with more aggressive rehabilitation protocol.

Shelbourne & Nitz, (1990) (see page 33) also studied the effect of an accelerated rehabilitation programme on patellar tendon reconstructions (compared to a more conservative rehabilitation programme). There were no significant differences between the two groups at one year. They concluded that the accelerated programme was more effective

than their initial rehabilitation programme as it reduced limitations of movement (especially knee extension) and loss of strength while maintaining stability and preventing anterior knee pain. The patients were divided into Group A (138 patients undergoing conventional rehabilitation) and Group B (247 patients undergoing accelerated rehabilitation).

Range of Movement: Group B achieved full flexion and extension before Group A. Twelve per cent of Group A underwent surgical intervention to regain full extension and 4% of Group B.

Isokinetic testing: Average quadriceps strength scores at 180°/s were initially higher in Group B but there was no difference between the groups at the two year follow-up.

KT1000: Group A averaged a side-to-side difference of 2mm at four to six months and 2,3mm at one year. Group B averaged a side-to-side difference of 1,8mm at four to six months and 1,8mm at one year.

Comment: Shelbourne & Nitz's study compared two different rehabilitation protocols in two groups of men and women treated by the same technique by the same surgeon. The accelerated programme emphasis full extension and closed kinetic exercises. (Closed kinetic chain exercises are performed with the foot placed on a surface (floor, step, pedal) and the entire limb bearing the load, causing all joints in the extremity to be compressed by the load). The results of this study only apply to bone - patellar tendon - bone reconstructions. The effect of this protocol on other grafts is unknown. In their accelerated programme, jumping, agility drills and stair climbers are allowed at five to six weeks. Although the authors claimed no complications of graft stretchout or patellofemoral crepitus, other patients may develop these complications if the reconstruction is stressed prematurely. They also allow their patients to return to sport as early as four months post-surgery. This premature return to sport often does not occur in clinical practise for various reasons - some surgeons feel it is too soon while some patients do not have 80% strength of the affected leg compared to the opposite leg at that time. Obviously surgical technique, patient compliance and motivation are also factors which may affect return to sport. There has been no further follow-up data on the accelerated programme to date. The authors did not comment on anterior drawer testing, Lachman testing, pivot shift or thigh atrophy. Crepitus and patellofemoral joint findings were not documented.

Shelbourne et al. (1991) (see page 54) in a different series, studied 169 patients who had undergone bone-patellar tendon-bone reconstructions. All patients had their reconstructions within eight weeks and were divided into three groups:

Group 1. 33 patients who had surgery within seven days;

Group 2. 21 patients who had surgery within 8 - 21 days;

Group 3. 71 patients who had surgery after 21 days post injury.

Group 1 and 2 were further divided into two sub-groups according to their rehabilitation programme - conventional rehabilitation or accelerated rehabilitation.

Range of Movement: There was a trend for Group 3 patients to regain early flexion and lack the least extension at a specific test date. No patient in any group lacked 10° or more of full extension. Patients following conventional rehabilitation exhibited a higher incidence of arthrofibrosis.

Isokinetic testing: Group 3 patients scored significantly higher than Group 1 patients at 13 weeks.

KT1000: Group 1 had an average reading of 1,8mm compared to 2mm for Group 2 and 1,7mm for Group 3.

They concluded that delaying surgery did not adversely affect objective results. There was actually a trend toward earlier return of both strength and flexion in Group 3.

Comment: All patients had their reconstruction within eight weeks after injuring their ACL. This would prevent chronic degenerative changes from developing which could affect the final outcome. One surgeon performed the surgery. The only objective parameters commented on were range of movement, Cybex results and KT1000 results.

Howe et al, (1991) (see page 34) in their study of 83 young, active patients who had undergone a reconstruction using the medial third of the patellar tendon found the following objective results:

Pivot shift: Ninety per cent did not have a positive pivot shift but 47% showed a pivot glide.

Range of movement: Eighty eight per cent had lost less than a 10° of movement (either flexion or extension) while 2,4% lost greater than 5° extension.

Laxity: A positive Lachman was considered to be a side-to-side difference of greater than 4mm (measured on the Genucom knee arthrometer). Eighty nine per cent had a negative Lachman. Unacceptable laxity was found in 15,6% (either clinically or objectively) and there was an overall failure rate of 19%. A positive pivot shift or Lachman was found in 19,3% and were considered to be failures.

Comment: Objective measurements of the knee ligaments were made using a Genucom Knee Evaluation System. This varied from the more commonly used KT1000, Lachman and anterior drawer tests. One examiner performed all measurements on the Genucom to prevent interexaminer variability. Four millimetres was used as a positive side-to-side difference as opposed to the more commonly used 3mm. This greater range of a side-to-side difference would result in more patients falling into this category, making their results look more impressive. Two examiners assessed the patients at follow-up, allowing for intertester variability. The authors did not comment on the anterior drawer, thigh atrophy, crepitus or the patellofemoral joint. Isokinetic testing was not performed. These factors resulted in a relatively poor assessment of the assessment.

O'Brien et al, (1991) (see page 35) reviewed 79 patients (80 knees) but 60% had additional iliotibial band augmentation. The results were as follows :
Laxity: Fifteen per cent had 1 + (1-5mm) anterior drawer and 2,5% 2 + (>5-10mm). Thirty five per cent had 1 + on Lachman testing and 6% 2+.
Pivot Shift: Sixteen per cent had 1 + (perceptible movement) or 2+ (clunk or jump).

Comment: Seventy-nine patients (but 80 knees) were assessed - thus one patient had bilateral knee involvement and neither knee could be used as a control. Sixty per cent of patients had additional augmentation using the iliotibial band. The authors did not comment on range of movement, thigh atrophy, crepitus or patellofemoral findings. Isokinetic testing was not performed. These factors constituted a relatively poor assessment of results.

Aglietti & co-workers, (1992) (see page 35) investigated 69 patients who had undergone a bone-patellar tendon-bone reconstruction. The average age was 23 years (range 15 - 40 years) and were followed up three to five years after the operation. Evaluation was performed using the Italian Knee Surgery Club Rating Scale - 50 points were given to the subjective parameters and 50 to the objective parameters. The following results were found:
Laxity: Ten per cent had a 1+ (0-5mm) pivot glide and 3% had a 2+ (5-10mm) pivot shift. Lachman testing was negative in 36%; 1+ (1-5mm) in 57% and 2+ (6-10mm) in 7%.
KT1000: At 20lbs, 65% had a 0-3mm side-to-side difference; 24% had 3,5-5mm difference and 11% greater than 5mm. Manual maximum testing found 56% with a side-to-side difference of 0-3mm; 32% a 3,5-5mm difference and 12% greater than 5mm.
Range of movement: Seven per cent had an extension loss of up to 5° and 8,5% had a flexion loss of up to 10° and 6% up to 15°.
Patellofemoral problems: No problems were found in 43,5% of patients, 35% had mild problems; 17,5% had moderate problems and 4% severe.
Crepitus: Pre-operatively 16% had mild patellofemoral crepitus. This increased post-operatively to moderate to severe patellar symptoms.

Comment: Aglietti et al used a different evaluation method which makes comparisons difficult. The authors did not comment on anterior drawer testing, thigh atrophy or isokinetic testing.

Rosenberg et al, (1992) (see page 36) in his study of ten patients following central third patellar tendon reconstructions found the following results :
Effusion: Ten per cent of patients had an effusion.
Range of movement : Thirty per cent of patients had a 5° limitation of extension.

Laxity: All knees were stable with a negative Lachman test and negative pivot shift.

Patella mobility: Twenty per cent had a decreased passive patellar tilt compared to the opposite side. Ten per cent had restrictions of both lateral and medial patellar glides.
Crepitus: Eighty per cent had a notable retropatellar crepitation during extension against resistance which was audible in the involved knee.

KT1000: All side-to-side differences were within 3,5mm of the non-involved knee. The average difference between the two knees was 1 7mm (increased laxity on the operated side) post-operatively and 7mm on the operated side pre-operatively.
Muscle strength: Isokinetic testing showed the quadriceps-to-quadriceps ratio to be decreased on the involved side. The largest decrease occurred at 60°/s with an average quadriceps deficit of 18%. The hamstrings were less affected - at 60°/s they showed an average deficit of 10% and no deficit at 180°/s. The peak torque in the quadriceps to body weight ratio at 60°/s was 78% compared to 96% of the non-involved side.
Thigh atrophy: This was measured at 5cm increments along the thigh. The maximum decrease occurred at 10cm above the superior pole of the patella, the average decrease being 0,8cm.
Computer tomography: Revealed a persistent defect in the patellar tendon. Ninety per cent of patients had scarring of the infrapatellar fat pad.

Comment: Only ten patients were assessed in this study, resulting in a possible bias in results. Patients not followed up could have had different results. Eighty per cent had extra-articular tenodesis - it is not known what role the tenodesis played in producing the side-effects. Their study is one of the few to use computer tomography and their findings that the tendon hypertrophies in cross-section but does not fill the gap if left open are invaluable to surgeons.

Buss et al, (1993) (see page 37) found the following on 68 knees who had undergone an ACL reconstruction (of which ten had augmentation using the iliotibial band) :
Lachman: Eighty eight per cent had 1+ or less (of which 43 were negative). Of the remaining eight knees with grade two, four had a firm end point indicating a structurally intact but lengthened graft and four had a soft end point indicating a non-functioning graft.
Pivot shift: (n=64) This was graded on a scale of 0-3. Eighty nine per cent were negative (grade 0); 3% had a grade one and 8% a grade two.
Range of movement: Normal extension (0° or more) was found in 92,6% of patients; 5,9% lost 1° - 5° and 1,5% lost 8° of extension. All knees flexed to within 10° of full flexion (compared to the opposite knee).

KT1000: Fifty six patients were tested by maximally stressing the knee in 30° of flexion. Sixty four per cent had 2mm or less side-to-side difference; 20% had 2 - 3mm; 9% had 3 - 4mm and 7% more than 4mm.

Comment: The Hospital for Special Surgery Evaluation was used to score the ligaments. This is yet another method of evaluation, making comparisons difficult. Additional augmentation was performed on 14,8% of patients but they were still included in the final results which could affect the final outcome. A 4mm side-to-side difference was used in their study, which would influence the number of patients falling into this category (compared to a 3mm side-to-side difference). Anterior drawer, thigh atrophy and the patellofemoral joint were not assessed. Isokinetic testing was not performed.

Glasgow et al, (1993) (see page 37) investigated the effect of early versus late return to vigorous activities on the outcome of 64 patients who had undergone a reconstruction using the medial third of the patellar tendon. The patients were divided into two groups :
Group A. Thirty one patients who returned to vigorous activity in less than six months;
Group B. Thirty three patients who returned to activity after six months.

Range of movement: The mean decrease of extension was -3° in Group A and B. The mean decrease of flexion was -4° in Group A and -5° in Group B (no significant differences). The mean time to return to final range of motion was 4,3 months for Group A and 5,4 months for Group B. Seventeen per cent underwent a manipulation of which 13% were in Group A and 21% in Group B.
Lachman: Negative in 74% of Group A and 66% of Group B.
Pivot Shift: Negative in 74% of Group A and 66% of Group B.
KT1000: At 20lbs, 84% of Group A and 82% of Group B had a side-to-side difference of 3mm or less. At maximum manual testing, 77% of Group A and 61% of Group B had a side-to-side difference of 3mm or less (not statistically significant on analysis by the authors).

The mean anteroposterior laxity differences with maximum manual testing were 0,98mm for acute reconstructions; 2,6mm for intermediate reconstructions and 3,1mm for chronic ACL reconstructions.

Manual strength: There was no significant differences between the two groups on isokinetic evaluation.

Comment: Only one surgeon performed the surgery but many additional procedures were performed at the time of surgery. The Philadelphia Knee Evaluation protocol was used, making comparisons in the literature difficult. Two authors performed the physical examination while another author performed the KT1000, Cybex testing and subjective evaluation. Anterior drawer testing, thigh atrophy and the patellofemoral joint were not evaluated.

Bach et al, (1994) (see page 38) in their study on 62 patients, found the following objective results :

Lachman: Symmetrical and normal in 77%; 19% had 0-5mm of movement with a firm end point.

Pivot shift: Ninety two per cent had a negative pivot shift; 3,2% had a trace pivot; 1,6% had a pivot of 1+; 3,2% had a pivot of 2+.

Range of movement: The mean range of extension was 0° (range of 8° of hyperextension to -10°) to 138° flexion (range 115° -150°). Twenty per cent had flexion contractures (defined as heel height difference greater than or equal to 1cm) of which 57% had a 1,5cm difference; 28,67% a 2cm difference and 14,3% a 3cm difference.

Crepitus: Sixty per cent had patellofemoral crepitation post-operatively (compared to 19% pre-operatively).

Thigh atrophy: Atrophy was noted in 75% of patients (mean = 1cm, range = 0-4cm). Thirty seven per cent had asymmetry of greater than 1cm. There was no statistical relationship between thigh atrophy and knee flexion contractures, chondromalacia, crepitus or tighter KT1000 results.

KT1000: The mean 20lb difference was 0,3mm (range = - 3mm to 12mm) and the mean maximum manual difference was 0,3mm (range = - 6mm to 16mm). Overall, 92% had a

manual maximum difference of less than or equal to 3mm. Three patients had a manual maximum difference of 3 - 4mm and three had a difference of greater than or equal to 5mm. Twenty eight per cent had tighter knees. There were statistically significant differences in the KT1000 results in the acute and chronic subgroups, with the acute group having more patients with smaller side-to-side differences.

Muscle strength: Evaluations were performed on the Cybex dynamometer at 60°/s, 180°/s and 240°/s. The mean quadriceps muscle deficits at 60°/s were 12% (range = -20% to 45%); 9% at 180°/s (range = -12% to 47%); 7% at 240°/s (range = -20% to 35%). A statistical correlation was observed between age (by decade) and Cybex dynamometer extension deficits (greater than 20%). No hamstring data was given.

Comment: This study is one of the few that had one surgeon performing the surgery and another evaluating the results to eliminate surgical bias. Various post-operative rating systems were used. Five millimetres was used as a significant side-to-side difference which is 2mm more than recommended by the International Knee Society. Twenty per cent of patients were lost to follow-up which could have affected the final outcome. Forty per cent had previous surgical procedures on the knee, some even undergoing two or three procedures before the reconstruction. Although atrophy was commented on, it was not stated which leg was affected. These previous procedures could affect the final outcome of the reconstruction. This report was commented on in detail, only the anterior drawer was not evaluated. Despite the detailed comment, this study has major flaws.

Wilk et al, (1994) (see page 39) assessed 50 patients who had undergone ACL reconstruction. They assessed the relationship between subjective knee scores, isokinetic testing and function.

Isokinetic testing: Seven per cent exhibited quadriceps peak torque to within 10% of the contralateral side at 180°/s and 300°/s. Fifty five per cent exhibited 90% strength level at 450°/s. Sixty six per cent exhibited hamstring strength within 10% at 180°/s, 74% at 300°/s and 86% at 450°/s.

Comment: This was a very detailed and interesting article. As the authors were evaluating relationship between subjective scores, isokinetic testing and function, not many objective measurements were made. The 50 patients were randomly selected. Most patients were assessed within 30 weeks of surgery, thus the long term effects are not known. It is not known whether these results would deteriorate with time. The details of surgery were not documented, nor is it known how many surgeons performed the surgery or how many clinicians were involved in the follow-up evaluation. Thus it is not known if there was any intertester variability. Isokinetic testing was performed on a Biodex dynamometer at 180°/s, 300°/s and 450°/s. The dynamometer used most commonly used in the literature is the Cybex dynamometer and different speeds are used. This makes comparisons difficult.

2.7.4 Functional results of patellar tendon reconstructions

Jones' (1980) (see page 30) study of 46 patients found that 41,3% had returned to some sort of athletic activity. Return to football with no restrictions were possible in 15,2% and with some restrictions in 2,2%. In the entire group, 59% patients returned without restriction to the usual activities they engaged in before injury and 37% had slight restrictions.

Comment: Jones' study did not comment on function. His return to sport data was very non-specific.

Johnson & co-workers, (1984) (see page 30) found the following results in their study of 87 patients :
Stair climbing: No problems were encountered by 85,2% of patients; 1,5% favoured the operated leg slightly; none found it difficult or impossible; 2,3% unknown.
Ability to squat: No problems were encountered by 54% of patients; 28,8% favoured their leg slightly; 5,7% found it difficult; 9,2% found it impossible and 2,3% unknown.
Ability to work: No problems were encountered by 88,5% of patients; 7% had to make minor modifications; 4,5% changed to a less vigorous job and none were unable to work.
Return to sport: Sixty nine per cent of patients were performing satisfactorily. Sports was possible in 25,3% of patients (none could participate in sport pre-operatively). Instability

or pain during heavy demands on the knee resulted in 43,7% of patients making slight modification of sports (compared to 5,8% pre-operatively). Twenty three per cent had moderate pain making light sports possible but none requiring cutting or turning (compared to 16,3% pre-operatively). Eight per cent found sports impossible due to pain and permanent instability (compared to 77,9% pre-operatively). Subjectively, 71% of patients were satisfied with their function at follow-up and 29% dissatisfied. No differences in functional results were correlated with patients age at the time of surgery. There was no tendency for results to deteriorate as follow-up duration increased. Comparison of functional results in patients who underwent ACL reconstructions only, ACL and MCL reconstructions with or without menisectomy and ACL with menisectomy revealed no differences, but patients who had undergone surgery prior to ACL reconstruction did not do as well functionally.

The mean loss of extension was 1,5° for patients with excellent functional results; 0,54° for patients with good functional results and 2,7° for those with fair functional results. Patients with poor function averaged 4° of hyperextension compared to the unoperated knees.
The mean loss of flexion was 4,3° for patients with excellent function; 5,8° for good function; 7,6° for fair function and 11° for poor function.

Mild/severe articular cartilage defects of the femur and tibia, MCL instability and meniscal tears observed at the time of surgery when considered individually against recovery classifications, did not increase the incidence of unsatisfactory functional results. Although a trend toward poorer functional results in patients who had undergone menisectomy before or during reconstructions was observed, no statistically significant trends were found.

Comment: The authors attempted to identify the reasons for the 27 unsatisfactory functional results. In many patients, several factors contributed - 11 patients had joint arthrosis, 11 had parapatellar pain, 10 had clinical evidence of complete ACL disruption and five had significant instability of other ligaments other than the ACL. In four patients, the reasons for failure were not apparent. One had clinical evidence of a torn meniscus and another had loose bodies within the joint.

The authors recognised the advantages and disadvantages of their retrospective study. The disadvantages include patients lost to follow-up, inadequate recording at the time of reconstruction for complete evaluation at follow-up. The advantages include the length of follow-up (five to ten years) and re-evaluation of patients at follow-up by physicians not involved in the original surgery.

The authors concluded that patients who had the least motion and the best end point to the Lachman and anterior drawer tests, had the best functional results. Arthrosis and parapatellar pain were the most frequently observed contributing factors to failure in the presence of a clinically intact ligament.

Bartlett & Crowe, (1985) (see page 30) found that 78% returned to vigorous sport (56% of footballers returned to playing football although they were advised to retire). Their results were classified "good" (return to full sporting activities, no giving way and a negative pivot shift); "fair" (improved function, no giving way and negative pivot shift) and "poor" (failed operation). According to their classification they found 85% good; 7,5% fair and 7,5% poor results. Further operations were required in 19%. There was no deterioration in results with increasing length of follow-up, all failures occurring early.

Comment: Although the authors commented on return to sport briefly, they did not comment on function. A re-operation rate of 19% is high but the authors did not state why this was needed or explain further.

Elmquist & co-workers, (1988) (see page 31) in their study of 29 patients, used the Lysholm score and performance tests to evaluate function. Using the value of 83 points (out of 100) as a limit between good-excellent and fair-poor results, they found 93% were excellent or good and 7% were fair. The patients with positive pivot shift signs also had the lowest Lysholm scores (65 points and 75 points) and were considered failures. Only 29% reached their pre-injury level of activity.

Four performance tests were evaluated :

1. running in a figure of eight;
2. one leg long hop;
3. running up and down a spiral staircase;
4. running up and down a 55m slope with two turns.

The tests were normal in 79% with minor abnormalities in 21%. No further details were given.

Only 29% of patients reached their pre-injury level of sporting activity. Activity levels increased significantly from a mean value of 3,9 (out of 11) pre-operatively to 6,3 (out of 11) at follow-up.

Comment: There was no detailed comments on return to sport in Elmquist et al's study. No details were given on the abnormalities in function in 21%. Although two examiners did the follow-up, there was a highly significant correlation between the two examiners. According to the authors they acknowledge that the mean follow-up time of 28 months was short.

Sandberg & Balkfors, (1988) (see page 32) did not evaluate function in too much detail in their study. The only point they commented on was that the Lysholm score and function remained constant with time.

Tibone & Antich, (1988) (see page 32) found 55% returned to their previous level of sport participation (18,1% unbraced and 36,4% braced). Thirty six per cent returned to limited or modified participation and 9% were unable to return at all.

Patients were asked to hop, squat (full and half), duck walk, stair climb, run on the spot and cutting in a straight line then in a crossed pattern. Forty five per cent had perfect scores in all eight functional tests. Nine per cent had discomfort while squatting while 18,1% were unable to squat fully. Nine per cent were unable to duck walk and 18,1% had discomfort

during this activity. No patient complained of discomfort while running on the spot. Discomfort was present in 27,2% of patients during hopping; 9% complained of discomfort during a half squat; 18,1% complained of discomfort while stair climbing, 9% complained of discomfort during straight cutting and 9% complained of discomfort while cross cutting.

Comment: The authors concluded that there was a functional improvement after ACL reconstruction. Objectively, although their instability improved there was still some increased laxity. As two procedures were used in this study, the per cent contribution of each procedure to the functional improvement of the patient is unknown. This study confirms, in a laboratory setting, that a patellar tendon reconstruction of the ACL can improve the functional status of the knee and enhance athletic performance.

Although the results in this study are promising, it must be pointed out that the population tested was very small (11 patients only), thus trends can become visible but definite conclusions are impossible to make. Also, five surgeons performed the ACL surgery and although they used similar techniques, it does allow for surgical variability.

Shelbourne et al, (1990) (see page 33) found that 60 of 69 varsity patients returned to their pre-injury level of competition the following season; eight chose not to return (for academic or non-medical reasons) and one tore his graft in a fall. Twenty varsity players were seniors and ineligible to return to competition the next season. Basketball (51) and football (49) accounted for 100 of the initial ACL injuries (the other sports being volleyball,softball, gymnastics and soccer).

They concluded: "return to sport has a predictably high success rate, few post-operative complications and low re-injury rate when the reconstruction is performed using a primary patellar tendon graft with excision of the ACL stump and is followed by the patients participation in an aggressive rehabilitation programme emphasising full extension."

Comment: Although the authors commented on patients returning to pre-injury level, they did not comment on how many patients changed sports and in what sports they were

participating post-reconstruction. Functional activities were only evaluated subjectively by questionnaire, none were actually performed in the follow-up evaluation. The subjective functional results were not documented in their data.

Howe & co-workers, (1991) (see page 34) followed up 83 active patients over ten years. Seventy six per cent qualified as satisfactory (defined as less than 4mm side-to-side difference on Lachman testing; no pivot shift (less than grade 2); no pain or only occasional pain with strenuous activities; no frank subluxation or no more than two episodes of "giving way" per year; sports participation).

Unsatisfactory results were found in 24,1% of patients - 2,4% had an intact graft but had significant pain; 2% had advanced degenerative changes (plus two surgical procedures before reconstruction); 1,2% had a positive pivot shift with no other clinical or symptomatic problems. Of the 15,6% patients evaluated by questionnaires, 4,8% were rated as unsuccessful. The incidence of failures did not increase as a function of time but patients operated on in the initial five years demonstrated more degeneration on x-ray than those in the last five years.

Although 91% regarded the condition of their knee to be worse than pre-injury, 82% had increased their level of activity relative to their pre-reconstruction/post-injury state. Fifteen per cent could not/did not increase their activity after reconstruction, although most had fewer symptoms. Lifestyle changes, rather than functional deficits were the cause for 2,4% of patients decreasing their level of activity. Overall 92% had no more than a mild functional deficit.

Functional analysis showed 81% of patients could climb more than 20 stairs without symptoms compared to 43% before reconstruction. The numbe patients who could walk more than one mile without mild pain increased from 45% (pre-reconstruction) to 82% (after reconstruction).

Howe, et al (1991) concluded that successful patients are likely to perform at 75% of their original level in the most strenuous sport group and at 92% in the least strenuous group. Averaging all patients, a 77% return to pre-injury performance level can be expected.

Comment: Howe et al's patients were subjectively analysed using a composite questionnaire devised by the authors (after consideration of many other rating systems). An eight point scale, explained in the article was used to subjectively assess function. A separate sports performance questionnaire was devised which assessed sports activity, stairs and walking before the injury, after the injury (but pre-reconstruction) and post-reconstruction. The only functional activities assessed in the study were walking and stair climbing and sport. The authors do not comment on the level of activity patients were involved in pre-operatively or post-operatively. Other functional activities e.g. hopping, squatting were not assessed.

Kaplan & co-workers, (1991) (in a continuation of the previous study) reviewed sports participation in the same group of patients (83 patients using quadriceps patellar tendon graft). Each patient was given a questionnaire qualifying their sports performance in 20 possible sports comparing three different periods (pre-injury, post-injury but before reconstruction and after reconstruction).

Different sports were classified into :-

Group A : most strenuous (maximal motion and strain on the knee) e.g. football, skiing, soccer;

Group B : moderately strenuous (moderate to maximal motion) e.g. gymnastics, tennis, baseball;

Group C : least strenuous e.g. golf, running, swimming.

Each sport was assigned a performance grade -

0 - no longer active because of pain/disabling symptoms;

1 - recreational participation with symptoms;

2 - strenuous participation with symptoms;

3 - professional sports with symptoms;

4 - strenuous activity with no symptoms;

5 - professional level with no symptoms.

A performance average was obtained from each group before injury, after injury but before reconstruction and after reconstruction.

Results: Analysis revealed a significant change in sports performance in each group for each time period. Patients began with a high rate of performance that decreased substantially after injury then rose to near, but significantly lower than their pre-injury level after surgery. Group A (the most strenuous sports) dipped to the lowest performance after injury and returned to the lowest level after reconstruction. Group C had the least loss in performance and returned to the highest level. Group B fell somewhere between.

The differences between group means according to these authors are significant at injury and after treatment but not pre-injury.

A comparison of successful versus unsuccessful results indicate a significant difference in overall trend over time. Unsuccessful patients do not rise to as high a performance level after surgery as successful patients. Successful patients are likely to perform at 75% of their original level in the most strenuous sports and 92% of their original level in least strenuous sports. An analysis of failures was difficult due to the small number of patients (20). Of the 20 patients, 13 had graft failure but their performance was no worse off than those classified as unsatisfactory due to persistent symptoms.

They concluded that patients make considerable performance gains once their knees have been stabilised and their sports performance directly correlates with the overall subjective and objective physical status. Taking all patients and averaging all sports groups, one can expect a 77% return of their pre-injury sports performance level after surgery.

Comment: Not all 83 patients were active in at least one sport for each of the three groups at all three stages (pre-injury, post-injury but before reconstruction and post-reconstruction). An analysis of data for the entire study is therefore incomplete and termed "unbalanced".

The balanced analysis allows for more relevant comparisons that are statistically significant. The reasons for the 20 failures was not discussed - the authors state that detailed analysis is difficult due to the small number of patients. Although the authors claim a 77% return of pre-injury sports performance level after surgery, this is dependant on the sport the patient is involved in and patient motivation amongst other factors.

O'Brien et al, (1991) (see page 35) found the following results in their study of 80 chronic ACL reconstructions (with 60% having iliotibial band augmentation): Sixty nine per cent were involved in the same level of activity as pre-operatively and 19% altered their level of activity due to changes in lifestyle. Fear of re-injury was the most commonly given reason for a change in activity. Forty per cent still wore a brace during sport but two-thirds did so because it gave them more confidence.

Comment: O'Brien et al did not comment on overall results or function. The authors did not comment on how many patients changed sports. They did not state what sports the patients were now involved in.

Aglietti & co-workers, (1992) (see page 35) claimed 75% excellent; 19% good and 6% fair results (using the Italian Knee Surgery Club Rating Scale). Of the 34 soccer players, 71% returned to the same sport, 23% decreased their activity because of problems unrelated to their knee and 6% because of their knee. Of the 13 basket volley players, 77% returned and 23% decreased activity but not because of their knee. Twenty-two patients played sky tennis of which 91% returned to their sport and 9% decreased their activity due to their knee.

Sixty per cent could participate fully in vigorous activities; 29% could jump and pivot with caution; 10% had a limited jump and pivot ability and 11% could run in a straight line only.

According to their knee rating scale, 6% were unsatisfactory but using clinical parameters (a positive pivot shift of 2+ or Lachman of 2+ or KT1000 side-to-side difference greater than 5mm at manual maximum test) 18,8% knees were unsatisfactory.

Comment: The authors do not explain what sky tennis or basket volley are or what actions they involve.

Rosenberg et al, (1992) (see page 36) tested functions of their ten patients using three tests:

1) single leg vertical hop;
2) long jump;
3) three hop jump.

The non-involved leg was compared to the involved leg. The average vertical hop decrease was 1,5 inch with the largest deficit being 4,5 inches. The long jump measurement on the involved leg averaged 4,1 inches less, with the largest deficit being 10,75 inches. The three hop jump averaged an 11,3 inch decrease with the largest deficit being 39,75 inches.

The functional tests revealed consistent deficits in the involved extremity. These tests may have greater implications for sports that involve jumping.

Thirty per cent stated that they were able to return to all their pre-injury activities.

Comment: It must be stated again, that this study only consisted of ten random patients. The sample is too small to make definite conclusions but a trend can be seen.

Buss & co-workers, (1993) (see page 37) classified each patient's level of participation in sports before the injury into three categories on the basis of the amount of cutting, deceleration and jumping required for the respective activities. Group A (41 patients) entailed the highest risk for giving way of the knee. e.g. soccer, basketball, gymnastics. Group B (25 patients) were associated with a moderate risk of giving way e.g. football, skiing, rugby. Group C included low risk sports e.g. jogging, swimming, bicycling (one patient).

Sixty eight per cent of patients in Groups A and B had returned to their pre-injury level of participation. Of the 41 patients in Group A, 59% had been able to return to their pre-injury level, while of the 25 who had been in Group B, 84% had returned to a Group A or

P activity. The most common reason for not participating in a particular sport was a change in lifestyle or a fear of re-injuring the knee.

Forty-nine patients, (72%) did not wear a brace for sports activities. Recurring episodes of giving way resulted in 1,5% of patients wearing a brace while 25% used a brace intermittently.

According to the ligament rating system of The Hospital for Special Surgery (maximum of 100 points), 65% had an excellent score (90 points or more); 22% good (80 - 89 points); 9% fair (70 - 79 points) and 4% poor (less than 70 points).

Pain was the most common reason for a lower score. Fifty six per cent had pain of which 57,9% were intermittently painful, 32% were painful during sport and 11% were painful during daily activities. Patellofemoral joint symptoms were severe enough in six patients to limit sports participation.

Comment: Once again, a different ligament rating system was used making comparisons difficult. Buss et al's study is one of the few studies that comments on bracing. A disadvantage of reviewing this report was the infrequent use of patient numbers and/or percentages, making comparisons difficult.

Glasgow et al, (1993) (see page 37). The effect of early versus late return to vigorous activities on the outcome of ACL reconstructions was assessed. The 64 patients were divided into two groups:

Group A : early return - 31 patients who returned to activity two to six months after reconstruction;

Group B : late return - 33 patients who returned to activity seven to 14 months after reconstruction.

After surgery there was no statistical difference in the highest activity level returned to by either group. No patients in group A and 9% in group B decreased activity secondary to

knee-related problems. No-one in group A and 6% in group B increased activity after surgery. Seventy four per cent of group A returned to their pre-operative level and 67% of Group B. Twenty six per cent of Group A and 33% of Group B decreased their activity level but not due to their knee. There were no significant differences between acute or chronic reconstructions when evaluated in terms of time to return to vigorous activity. Knee rating scores (using the modified Cincinnati Score) for both symptoms and function were not significantly different. They concluded that an early return to activity, at a mean of five months, does not predispose patients to re-injury - nor does it predispose patients to a less satisfactory result (as determined by KT1000 arthrometer or subjective assessment).

Comment: As stated before, patients undergoing additional procedures were included in Glasgow et al's study. Yet another knee rating system was used for evaluation (the modified Cincinnati Knee Rating System and the Philadelphia Knee Evaluation protocol). Although these patients returned to vigorous cutting activities, the authors did not state if the patients returned to the same level of participation as pre-injury. No assessment of function (i.e. functional activities) were tested at follow-up. A weakness of their study is that the authors do not comment on the patients' overall results.

Bach et al, (1994) (see page 38) used the following tests to measure function : single-legged hop, vertical jump and timed single jumps over a 20 foot distance. On single-legged jump, the reconstructed knee was 88% of the normal knee (range 60% - 145%); 87% of the normal knee on vertical jumping (range 39% -137%) and 90% of the normal knee on timed single jumps over a 20 foot distance (range 70% - 126%).

There was no statistically significant differences in these functional activities in the acute or chronic sub-group, those with thigh girth atrophy, knee flexion contractures or meniscal involvement. There was no statistically significant differences in the single-legged hop or timed single-legged hop in patients with post-operative patellofemoral crepitation but the vertical hop was significant. In patients with patellar pain syndromes,there was a statistical significance with the single-legged hop but not with the vertical jump or timed single-legged jump.

Wilk et al, (1994) (see page 39) assessed the relationship between subjective knee scores, isokinetic testing and functional testing in 50 ACL reconstructions.

Seventy per cent could participate in sports but felt they must guard their knee. Four per cent were unable to participate in any sporting activity. Sixteen per cent felt their knees were satisfactory and without limitations. Seventy one per cent had difficulty climbing up stairs and 18% were uncomfortable with competitive unlimited running. Eighty two per cent were apprehensive about jumping and twisting activities. Only 14% felt they could perform unrestricted jumping. There was an inverse relationship between patients age and self-assessed knee function - as age increased, the subjective knee score decreased.

Sixty four per cent demonstrated normal limb symmetry (85% or greater) on the three single leg hop tests. Forty seven per cent demonstrated on abnormal limb symmetry (less than 85%) during the single leg hop for distance and 44% during the single-leg cross-over triple hop. Twenty six per cent exhibited abnormal limb symmetry with the single-leg hop for time. Significant values were found between the subjective knee score and timed hop and the cross-over test.

According to these authors, the single-leg hop for time and cross-over hop are the most sensitive tests and the best indicators of function. Most patients were more apprehensive with the cross-over hop test and the timed hop test.

A positive correlation was found between knee extension peak torque (at 180°/s) and the timed hop, hop for distance, and triple cross-over hop.

According to subjective questionnaires on knee function, 47% scored greater than 90 points (out of 100) with 16% scoring over 95 points. Noyes' system allows patients with over 85 points to resume jumping, cutting and hard pivoting. Thus 68% of the patients in Wilk et al's series could return to vigorous sports on a regular basis.

Comment: Results of correlation between isokinetic testing and function are conflicting. Many have found no correlation while others have found positive correlations - this inconsistency could be due to differences in populations, pathologic conditions, method of testing and equipment. Wilk et al found a positive correlation between quadriceps strength at 180°/s and 300°/s and the three hop tests. No correlation was found in their study (or any other study) between hamstring strength and/or hamstring/quadriceps ratios and functional performance.

Wilk et al's study is well researched and innovative. It discusses the relationships between subjective results, isokinetic testing and function. It is also the first study to examine the concept of limb acceleration and deceleration during high speed isokinetics. It does not comment on how many authors performed the evaluation.

3.0 MATERIALS AND METHODS

The aim of this study is to assess the success of ACL reconstructions of a single orthopaedic surgeon using the following criteria:

1) Clinical assessment of pain, stability and function;
2) Subject satisfaction;
3) Subject's ability to return to his pre-injury level of sport;
4) Subject's compliance with the rehabilitation programme (and if it affected the outcome);

A list of patients who had previously undergone patellar tendon ACL reconstructions was obtained from one orthopaedic surgeon who specialises in knee surgery. This was done to eliminate surgical variability.

Ethical clearance was obtained from the Committee for Research on Human Subjects (Medical)- Ethical Clearance Certificate Number M930408.

3.1 Exclusion criteria:

In order to exclude as many variables as possible and to keep as homogenous a group of patients as possible the following were excluded :

1) females;
2) males younger than 20 and older than 35;
3) previous surgery on the operated knee besides diagnostic arthroscopies;
4) post-operative follow-up time less than 12 months;
5) any other ligamentous injuries to the knee besides ACL injury;
6) other methods of reconstructing the ACL.

Due to the mechanism of injury of the ACL, isolated ruptures occur rarely. For this reason, patients who underwent menisectomies at the time of reconstruction were included

in this study.

A list of almost 200 patients was obtained from the orthopaedic surgeon's files.

From that list the following were excluded :
Thirty six women, 24 subjects who had had previous operations before their ACL reconstruction, 34 subjects who had had other methods of reconstructing the ACL and four subjects who were less than 12 months post-surgery. Twenty-three subjects were too old and six subjects were too young. Five subjects had additional ligamentous injuries and four subjects had further surgery since their reconstruction. Twenty subjects lived outside the Gauteng area and 16 subjects were untraceable.

This resulted in 20 subjects being available for evaluation in this research report.

3.2 Surgical technique

Anterior cruciate ligament patellar tendon reconstruction technique (Firer, 1993)

Under anaesthesia with tourniquet control the knee is flexed over the end of the operating table in a leg holder. After routine examination under anaesthesia, a diagnostic arthroscopy is carried out confirming the diagnosis of a torn anterior cruciate ligament and establishing any other meniscal or articular pathology. These are treated accordingly.

Through a central longitudinal incision from the lower pole of the patella to the tibial tubercle, a 9 or 10mm width of patella tendon is harvested with a 2cm x 5mm bone block of both patella and tibial tubercle. Drill holes are made through these bone blocks to pass sutures for the passage of the ligament into the joint. Under arthroscopic control, guide wires are inserted into the anatomical site on the tibia and femur of the insertion of the anterior cruciate ligament. These are overdrilled with the correct size drill bit depending on the size of the graft that has been taken. The graft is then passed through these drill holes, being fixed in each bone tunnel with an interference screw. The ligament is

tensioned such that it is in maximum tension in extension and fixed in this position. The wound is closed routinely over a portovac drain.

This procedure, as described by the surgeon, was used on all patients in this study, eliminating the element of surgical variability.

3.3 Equipment used in this study

3.3.1 Plinth or examination bed.
3.3.2 Goniometer to measure joint range of movement.
3.3.3 Tape measure to measure girth of thigh.
3.3.4 Stop watch.
3.3.5 Cybex II isokinetic dynamometer to measure muscle strength.
3.3.6 KT1000 knee arthrometer to measure ACL laxity.

Method: All subjects were initially c ⁻ted by telephone. The procedure was explained and they were informed that participation in this assessment programme was voluntary. An appointment date was scheduled. On meeting, the subject was reminded that participation was voluntary. He could refuse to participate or withdraw his consent or participation at any stage without prejudicing future examination or treatment. Informed consent was obtained from each subject. (Appendix A) (See page 153).

3.4 Questionnaire (Appendix B) (See page 155)

The researcher and subject completed a questionnaire together.
The questionnaire covered :
Personal details;
General residual symptoms :

i) pain;
ii) muscle weakness;

iii) giving way or locking.

Sports
Operation and rehabilitation.
Re-injury.
Functional assessment.

Further details were obtained if any question was answered in the affirmative. e.g. Do you have pain? Yes/No. If yes, when, on what movement and for how long?

Details on sports involvement before their injury and at follow-up were obtained to see if the patient had returned to his pre-injury level of activity.

The section on rehabilitation was important to assess patient compliance and motivation. It also included their perceptions about surgery i.e. if they were happy with their outcome and if surgery had been worthwhile.

A functional assessment was included to assess how the patient's knee was functioning during their normal day and during sports activities. Their working capacity was rated as was their impression of their knee function at three different stages (pre-injury, after the injury but before surgery and at follow-up). This was then correlated with the objective examination.

They were also asked at what intensity of activity certain residual symptoms (swelling, pain, apprehension) appeared and if they had any functional disabilities during walking, squatting, running, up and down stairs, jumping or zigzagging.

3.5 Physical examination (Appendix C) (See page 163)

This included :

3.5.1 Function;
3.5.2 Range of movement;
3.5.3.1 Lachman test at 25°;
3.5.3.2 Anterior drawer test at 90°;
3.5.4 Pivot shift;
3.5.5 KT1000 tests for ACL laxity;
3.5.6. Varus and Valgus strains;
3.5.7 Quadriceps girth;
3.5.8 Patellofemoral joint findings;
3.5.9 Medial and lateral compartment findings (including McMurray test)
3.5.10 Isokinetic tests of muscle strength on Cybex II isokinetic dynamometer.

3.5.1 Function.

Patients were asked to hop side-to-side on one leg for as long as they could manage up to one minute. The number of hops was recorded by the researcher. Both the operated and unoperated knee were tested.

The patient was asked to squat on each leg (holding on to a support for balance if necessary) and to rate the ease of this activity (i.e. easy, difficult, unable). Both knees were tested. A duck squat (squatting on both legs and walking one metre) was performed, again rating ease of activity.

Within an area of five metres by two and a half metres, the patient was asked to :-
i) run there and back in a straight line, five times;
ii) run in a premarked figure of eight, five times;
iii) run in a premarked zigzag pattern, five times.

These activities were timed by the researcher and compared to times of 20 controls (active males within the age group 20 - 35 with no knee problems).

3.5.2 Range of movement.

The patient lay supine while the examiner measured the range of knee extension and flexion using a goniometer with the greater trochanter and lateral malleolus as bony landmarks (American Academy of Orthopaedic Surgeons, 1986).

3.5.3 Tests for ACL laxity.

There are two tests which measure the laxity of the ACL :-

a) Lachman test at 25° of knee flexion.

b) Anterior drawer at 90° of knee flexion.

The pivot shift assesses anterolateral instability due to ACL deficiency.

3.5.3.1 Lachman.

This is reportedly the most reliable test for ACL laxity (Johnson and Warner, 1993) with a sensitivity of 87% (Johnson et al, 1984) to 98% (Donaldson et al, 1992). It is reliable due to :

i) the position being comfortable for the patient;

ii) the mechanical advantage of the hamstrings being negated;

iii) the contact area on the lateral tibial articular surface being slightly convex which reduces the co-efficient of static friction;

iv) the wedge effect of the posterior horn of the medial meniscus being decreased in 25° flexion compared to 90° (Firer, personal communication, 1995).

Method: The patient's knee is flexed approximately 25°. The examiner uses one hand to stabilise the femur by grasping the distal thigh posteriorly, proximal to the patella. The other hand grasps the tibia at the level of the tibial tubercle. Firm pressure is applied to the

posterior aspect of the tibia in an effort to produce an anterior translation. The amount of translation is recorded in millimetres (Bonnarens & Drez, 1987).

A ruler is placed on the bed and the amount of movement is visually estimated as the researcher's hands move during the test. The test must be performed bilaterally. A more accurate method of reporting Lachman values is as a side-to-side difference as it takes into account the normal laxity of the other leg. e.g. If a patient has a Lachman value of 7mm on his operated knee and 5mm on his unaffected knee, his side-to-side difference would be 2mm. This side-to-side of less than 3mm would be considered normal. The same applies for reporting anterior drawer measurements (see page 76) and KT1000 results (see page 81). This researcher has chosen a side-to-side difference of greater than 3mm to indicate abnormal laxity of the ACL, (International Knee Society Standard reporting form). Clinically, grades of 1+, 2+, 3+ may be used. Grade 1+ denotes anterior translation of 0-5mm, 2+ denotes translation of 5-10mm and 3+ greater than 10mm.

The end point of the test is recorded and can be solid, semi-solid or soft. A soft end feel indicates a torn or totally non-functional ACL. A false positive test may occur with a PCL injury.

The integrity of the PCL is checked by a negative posterior drawer sign and the presence of a step-off between the medial tibial plateau and medial femoral condyle.

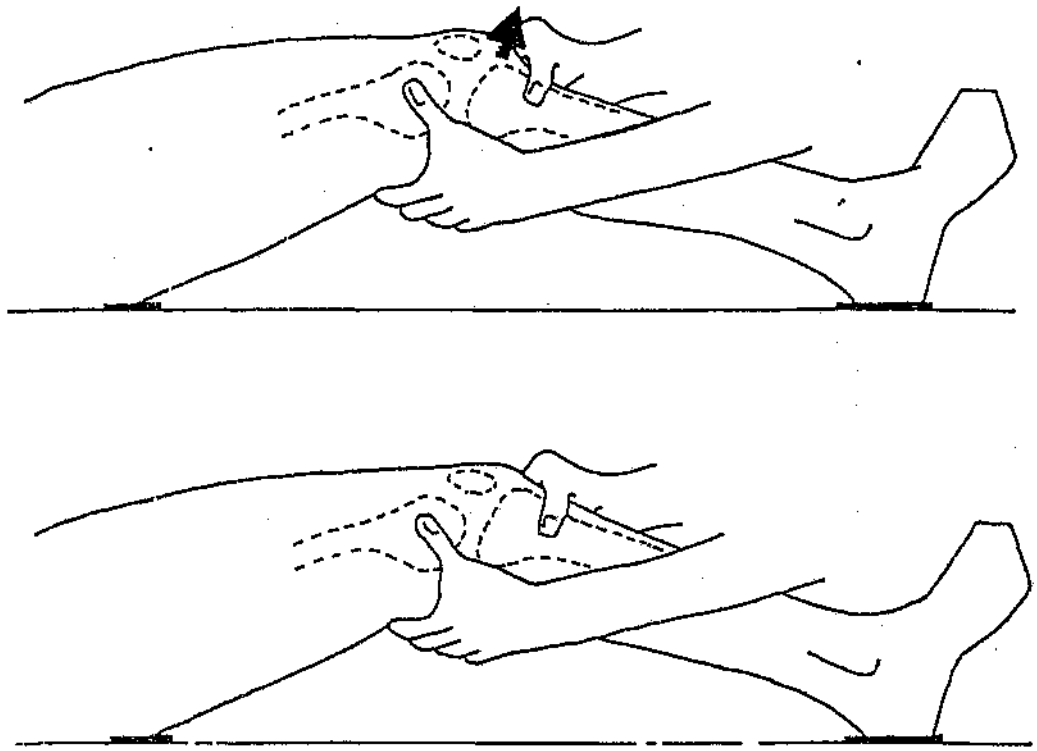

Figure 3.1 - Lachman Test (From Bonnarens, F.O., Drez, D. Jnr. 1987, Clinical examination of the knee for ACL laxity. In: Jackson, D.W. & Drez, D. Jnr. *The anterior cruciate deficient knee : New concepts in ligament repair.* St. Louis, C.V. Mosby. : p 76, with permission).

3.5.3.2 Anterior drawer test.

This test measures ACL laxity at 90° knee flexion but is less reliable (Katz & Fingeroth, 1986, Johnson & Warner, 1993) especially in the acutely injured patient who has a painful swollen knee with hamstring spasm.

Method: The patient lies supine with the hip flexed 45° and the knee flexed 90°. The patient's tibia is in neutral rotation with the foot flat on the table. The examiner's hands are placed over the proximal tibia. The index fingers palpate the hamstrings to ensure relaxation while the thumbs are placed on the tibial plateau and the joint line. The examiner sits on the patient's foot to stabilize the leg. A smooth, steady pull is then made in an anterior direction (Bonnarens & Drez, 1987). The amount of translation is recorded and is compared to the opposite side. A side-to-side difference of greater than 3mm is indicative of ACL laxity (as for the Lachman sign).

Although the same clinical grading of 1+, 2+, 3+ is often used to indicate the amount of anterior translation, in this study, more precise readings were used.

The end feel should be recorded as solid, semi-solid or soft.

The test should be repeated in internal and external rotation of the tibia. Internal rotation assesses the integrity of the posterolateral corner structures (of which the iliotibial band acts as the "primary restraint to clinical and functional forces" (Butler et al, 1980) while external rotation assesses the posteromedial structures (the MCL is the primary restraint during clinical forces but the ACL is the primary restraint with functional forces).

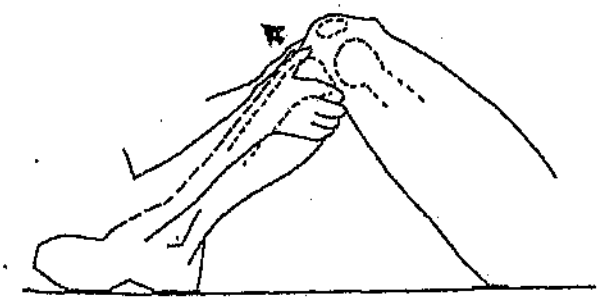

Figure 3.2 - The Anterior Drawer test (From Bonnarens, F.O., Drez, D. Jnr. 1987, Clinical examination of the knee for ACL laxity. In: Jackson, D.W & Drez, D. Jnr. *The anterior cruciate deficient knee : New concepts in ligament repair.* St. Louis, C.V. Mosby.: p 75, with permission).

3.5.4 Pivot shift.

This test for anterolateral instability is a combination of anterior and posterior translation and internal and external rotation. Many tests are described (Bonnarens and Drez, 1987) which provide a valgus thrust to the knee during flexion and extension to accentuate the subluxation or reduction of the tibia. ACL insufficiency leads to disruption of the translation-rotation mechanism resulting in anterior subluxation of the lateral tibial plateau as the knee is brought into extension because of the action of quadriceps and iliotibial band pulling the tibia forward. Conversely, when the knee is flexed the iliotibial band moves posterior to the centre of rotation of the joint reducing the tibia i.e. the tibia moves back to its original position (Bonnarens and Drez, 1987).

The pivot shift phenomena can be explained using the knee kinematics. The joint surfaces undergo sliding and rolling during flexion. The precise ratio varies with joint position. The cruciates are the dominant ligamentous restraints controlling this ratio (Bonnarens & Drez, 1987).

In the ACL deficient knee, rolling dominates during early flexion (Tammea & Henning, 1981) causing the tibia to sublux anteriorly.

The iliotibial band plays a central role in the pivot shift. Normally, the iliotibial band acts as a knee extensor when the knee is extended because its mean line of force is anterior to the flexion axis of the knee. In full flexion, the iliotibial band's mean line of force is posterior to the flexion axis and therefore functions as a knee flexor. There is a critical point between 20° - 30° flexion when the mean line of force intersects with the central axis. Flexion past this point converts the iliotibial band function from extensor to flexor. This transition is smooth if the knee ligaments are intact (Bonnarens & Drez, 1987). If the ACL is ruptured, anterior translation of the tibia can occur over the femur as the knee goes into extension. This results in an increase in tension on the iliotibial band due to abnormal lengthening during this phase. Once the knee is flexed past the critical point, the iliotibial band becomes a flexor and pulls the tibia posteriorly into the reduced position. The tibia will

continue to be held in the reduced position for the remainder of knee flexion. Thus the iliotibial band functions as a dynamic restraint against anterior laxity. The sudden reduction is the "pivot shift" (Bonnarens & Drez, 1987).

Method: The examiner uses one hand to grasp the patient's ankle and places the other hand with the heel of the hand over the lateral head of the gastrocnemius and the palm of the hand behind the fibula. The patient's knee is fully extended and internally rotated with the examiner's hand near the ankle. A valgus strain is applied as the knee is slowly flexed. The tibial plateau will be in a forward subluxated position initially. With flexion the subluxation will reduce, often in a dramatic way. This is a positive test. If the test is grossly positive, the tibia impinges on the femur inhibiting reduction (Bonnarens & Drez, 1987) and can be very painful.

The result is graded by estimating the amount of tibial motion that occurs. It can be graded as O (absent), 1 + (glide), 2 + (moderate), 3 + (momentary locking/severe).

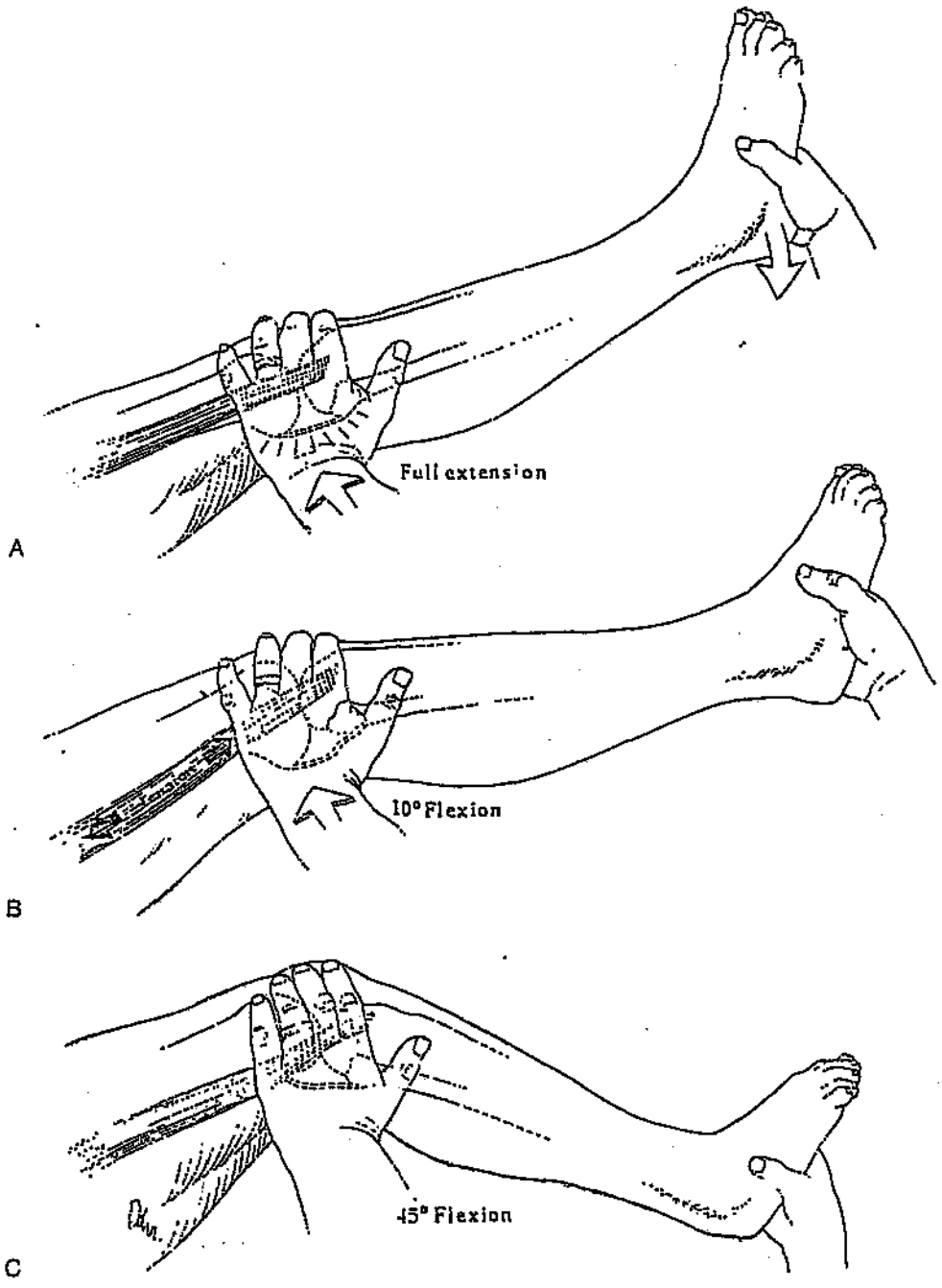

Figure 3.3 - Pivot Shift. (From : Losee, R.E. 1988. The pivot shift. In : Feagin, J.A. (Ed) *The crucial ligaments*, New York, Churchill Livingstone. p 301-314, with permission).

3.5.5 KT1000

This test is an objective measurement of ACL laxity. The arthrometer (Medmetric KT-1000) is placed on the anterior aspect of the leg and is held in place by two circumferential velcro straps. There are two sensor pads :

1, one in contact with the patella;

2) one in contact with the tibial tubercle.

These pads move freely in the anterior-posterior plane in relation to the arthrometer case. The instrument detects the relative motion (in millimeters) between the two sensor pads and therefore motion of the arthrometer case (as the calf compresses under the velcro straps does not affect the instruments output). Displacement loads are applied through a force sensing handle which is located 10cm distal to the knee joint line (Losee, 1988).

Two tests were performed using the KT1000 (in this study):

1) 30° flexion test;

2) maximal manual test.

Method:

3.5.5.1 30° flexion test. The examiner places an 11cm support under both thighs and adjusts the footrest so that both limbs are in an equal position of flexion (approximately 30°) and rotation (0° - 20° external rotation). The positioning supports do not constrain tibial internal rotation. The lateral aspect of the foot rests against the foot support, which partially constrains tibial external rotation. Pressure on the patellar pad must be maintained throughout the test and it must remain constant (variation in pressure will alter the position of the patellar sensor pad secondary to soft tissue and cartilage compression resulting in spurious measurements). The instrument dial is set at zero. A 20lbs (89N) posterior force is applied followed by a 20lbs (89N) anterior force and the displacement is read directly off the dial. The dial should return to zero. If not, recalibrate to zero. The test is repeated three times and the average figure recorded. Each knee is tested.

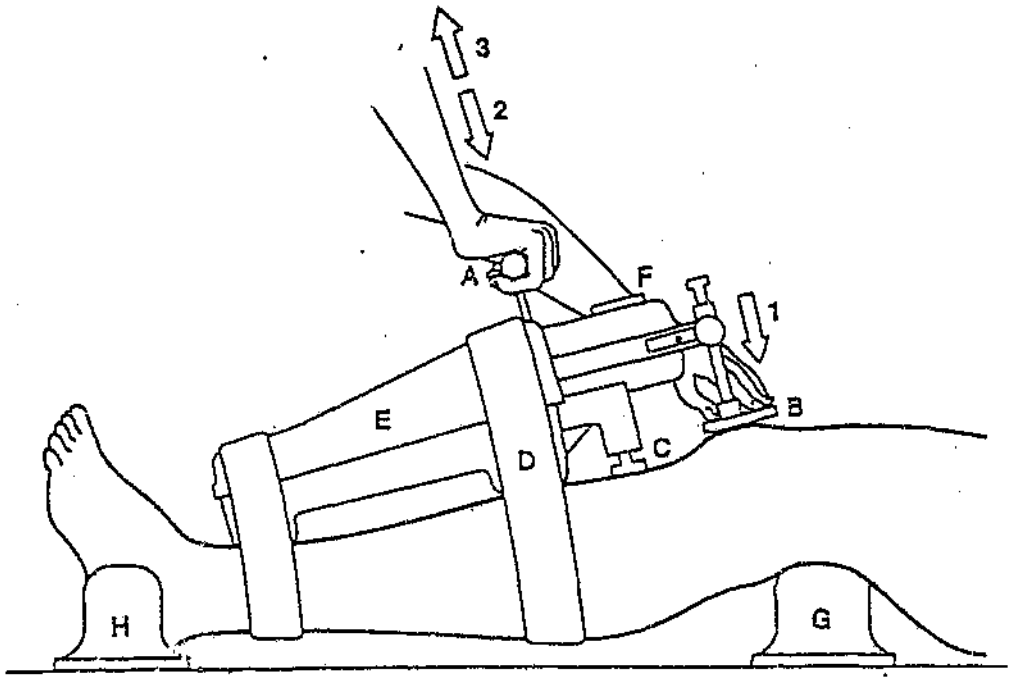

Figure 3.4 - Arthrometer model of KT1000 where :

A = force handle, B = patellar sensor pad, C = tibial tubercle sensor pad, D = Velcro strap, E = arthrometer case, F = displacement dial indicator, G = thigh support, H = foot support. 1 = constant pressure of 4 - 6 pounds applied to the patella, 2 = posterior force applied, 3 = anterior force applied.

(From : Losee R.E. Diagnosis of Knee Ligament Injury. Tests and Measurements of Joint Laxity. In : Feagin, J.A. (Ed) *The Crucial Ligaments,* New York, Churchill Livingstone. p 301-314, with permission).

3.5.5.2 Manual Maximum Test.

The patient is set up as for the 30° flexion test. The patellar sensor pad is stabilized with one hand, while the examiner's other hand applies as strong an anterior force as possible directly to the proximal calf (as opposed to the force handle), ensuring that the knee is not extended during this action. The tibial displacement is read off the dial (Losee, 1988). This test is performed three times on each knee and the average for each knee is recorded.

3.5.6 Varus & Valgus stresses.

Valgus (abduction stress) and varus (adduction stress) angulation was measured at 0° and 25° of knee flexion

Valgus test.

Method: The patient lies supine and the knee is held at 0° for the first test and held at 25° - 30° of knee flexion for the second test. The examiner places one hand over the lateral aspect of the knee and grasps the foot or ankle with the other hand. An abduction stress is applied to the knee (Hughston et al, 1976). The amount of medial "joint line" separation is estimated (as an indicator of laxity). This is recorded as 1 + (0-5mm), 2 + (5-10mm) and 3 + (greater than 10mm).

Varus test is repeated as above but the examiner's hand is placed over the medial aspect of the knee and a varus stress is applied.

3.5.7 Quadriceps girth.

Quadriceps atrophy was assessed by measuring the circumference of the thigh at 5cm and 10cm proximal to the superior pole of the patella and across the middle of the patella using a tape measure and compared to the opposite leg (Rosenberg et al, 1992). This tape measure, a standard dressmakers tape measure, was made of linen covered with plastic. The same tape measure was used on all subjects. This type of tape measure is a non-

extensible piece of apparatus, therefore its reliability is acceptable.

3.5.8 Patellofemoral joint.

The patellofemoral joint was tested for transverse and longitudinal movements, crepitus, pain and/or tenderness and lateral or medial instability.

Transverse and longitudinal movement: Patella mobility was assessed by moving the patella medially - laterally and superiorly - inferiorly. The amount of movement was then compared to the opposite knee.
Crepitus: The subject actively extended his knee against resistance while the examiner palpated the patella. This was graded as mild, moderate or severe.
Tenderness: The patellofemoral joint was palpated for pain and tenderness.

3.5.9 Medial and lateral compartment of the knee.

The medial and lateral compartments were palpated for crepitus, tenderness and signs of meniscal damage, elicited by the McMurray test.

Method: The patient lies supine and the leg is taken from full knee flexion to extension, while the foot is retained first in full internal rotation and then in full external rotation. To examine the right knee, the left hand of the examiner is placed on the knee with the thumb over the lateral joint line and with the first and second fingers over the medial joint line while the right hand maintains the rotation of the tibia. At no times is a valgus or varus stress applied to the knee (Evans et al, 1993).

3.5.10 Isokinetic muscle strength testing

Isokinetic muscle strength was measured on a Cybex II isokinetic dynamometer. The quadriceps and hamstrings of both legs were tested at three different speeds.

Method: The Cybex dynamometer was calibrated before each subject was tested. The patient warmed up for five minutes on the stationary bicycle. Each patient was tested in the seated position and stabilisation straps were applied across the trunk (like a seatbelt) and across the thigh. The resistance pad was placed at a level one inch proximal to the medial malleolus. The non-involved limb was tested first. Both limbs were weighed to compensate for the effects of gravity.

The test was performed at three speeds : 60° per second (for strength) i.e. 60°/s; 180° per second (for power) i.e. 180°/s and 240° per second (for endurance) i.e. 240°/s.
At each speed, four warm ups were allowed (three submaximal and one maximal) before testing. At 60° per second, three maximal concentric contractions were performed, at 180° three maximal contractions performed and at 240° per second, 30 maximal contractions were performed. A rest of 30 seconds was allowed between speeds to minimise fatigue. Verbal commands were standardized during testing. The test was repeated on the operated leg.

The values to be assessed were defined as :
i) Peak torque = the single highest point of the graph, regardless of where in the range it occurs (Davies, 1992) and indicates maximum muscular tension capability.
ii) Average power = total work (i.e. total area under the torque graph) divided by the time it takes to perform the work (Davies, 1992).
iii) Endurance ratio = the ratio that occurs as the muscle exercises and fatigues. A certain number of repetitions are compared at the beginning and end of the test and the percent change is calculated (Davies, 1992). In this test of 30 repetitions, the work done in the last 20% of the set is divided by the work done in the first 20% of the set and then multiplied by 100.

3.6 Statistical analysis

The student two tailed t-test was used for statistical analysis of data obtained in this study. A rejection level of $p=0,05$ was used in this study.

4.0 RESULTS:

In this study, 20 men aged 20 - 35 (mean = 28,84 years, range = 22 - 34 years) were assessed following an ACL reconstruction using the patellar tendon. Average time of follow-up was 28,4 months with a range of 13 months to 48 months.

The intervals between injury and reconstruction were classified as acute (less than 6 weeks), subacute (6 - 12 weeks) and chronic (greater than 12 weeks). Seven (35%) acute reconstructions were performed (range four days to four weeks), three (15%) subacute reconstructions (range two to three months) and ten (50%) chronic reconstructions (range five months to 60 months).

4.1 Surgical procedures at time of reconstruction

Three subjects had an ACL reconstruction only (13,6%). Ten subjects (45,5%) had medial meniscus involvement of which four had a partial menisectomy, and three a subtotal menisectomy and three a medial meniscal repair. Nine patients (40,9%) had lateral meniscal involvement of which eight required lateral repair while one subject had his synovium shaved to allow self healing in a small tear. Two (9%) had both medial and lateral meniscal involvement. One of these required a subtotal medial menisectomy and a lateral menisectomy while the other required a subtotal medial menisectomy combined with a lateral meniscal repair.

Therefore ten (45,5%) had medial meniscal involvement;
nine (40,9%) had lateral meniscal involvement;
of which two (9,0%) had both medial and lateral meniscal involvement;
three (13,6%) had an "isolated" ACL injury.

4.2 **Activity at the time of injury**

Table 4.1

Activity at the time of injury	
Sport	Number (%)
Soccer	11 (55%)
Rugby	3 (15%)
Squash	2 (10%)
Motor cross	1 (5%)
Hockey	1 (5%)
Badminton	1 (5%)
Skiing	1 (5%)
TOTAL	20 (100%)

4.3 **Pain at follow-up**

All patients who had pain in their knee at ANY stage of rest or activity (even momentary pain) were recorded as positive. Thirteen (65%) complained of pain and one (5%) complained of discomfort i.e. six (30%) were totally painfree.

4.3.1 Pain provoking factors

Table 4.2

Provoking Factors	Number (%)
Strenuous activities e.g. pivoting, jumping, deceleration	11 (40,7%)
Moderate activities e.g. jogging,tennis,hiking	4 (14,8%)
Awakening in morning	2 (7,4%)
Kicking a ball	1 (3,7%)
At rest	1 (3,7%)
In the evening	1 (3,7%)
Cold weather	1 (3,7%)
None	6 (30 %)

Note: More than one factor could provoke pain, therefore n = greater than 20.

4.3.2 Pain provoking activities

Table 4.3

Provoking Activities	Number (%)
Kneeling	8 (25,8%)
Jumping	8 (25,8%)
Standing	2 (6,5%)
Pivoting	2 (6,5%)
Stairs	2 (6,5%)
Sitting	2 (6,5%)
ZigZag	1 (3,2%)
No activities	6 (19,4%)

Note: More than one factor could provoke pain

4.3.3 Site of Pain (n = 20)

Table 4.4

Site of Pain	Number (%)
Infra patella	4 (20%)
Anterior knee	4 (20%)
Behind the patella	4 (20%)
Lateral patella	1 (5%)
Medial patella	1 (5%)
No pain	6 (30%)

4.3.4 Duration of Pain (n = 20)

Table 4.5

Duration of Pain	Number (%)
Momentary	6 (30%)
1 - 30 minutes	4 (20%)
30 - 60 minutes	1 (5%)
Longer than 1 hour	1 (5%)
Longer than a few hours	1 (5%)
Longer than 1 day	1 (5%)
No pain	6 (30%)

4.4 Stiffness

This was defined as a subjective sensation of tightness around the knee joint. Thirteen subjects (65%) had no stiffness, two (10%) complained of stiffness on awakening in the morning, two (10%) were stiff at rest and three (15%) were stiff after activity. Of the seven subjects complaining of stiffness, only one had full range of movement.

4.5 Muscle weakness

Twelve subjects (60%) perceived a difference in muscle strength (of which, one (5%) felt the unoperated leg to be weaker than the operated leg). Eight subjects (40%) felt no difference in strength between their two legs.

4.6 Giving way

Giving way could be due to muscle weakness or anterolateral laxity (causing a pivot shift type of giving way). The patients who complained of giving way had difficulty distinguishing or remembering if it was a feeling of giving way or an actual incident. Fourteen (70%) had no incidence of giving way since the operation. Of the six (30%) who complained of giving way :

- one (5%) felt that a change in direction provoked his giving way;
- four (20%) had one - two incidents with twisting or jumping;
- one (5%) complained of giving way with moderate activity especially running and occasionally with walking;
- one (5%) complained of giving way on his return to soccer following the reconstruction. He has since given up soccer and the knee no longer gave way.

4.7 Locking

None of the patients complained of locking since the operation (100%).

4.8 Pre-operative sports participation versus post-operative participation

Table 4.6

Sport	Number involved Pre-operatively	Number involved Post-operatively	Change in Participation
[illegible]er	11	4	-7
[illegible]y	3	-	-3
[illegible]sh	3	9	+6
[illegible]minton	2	-	-2
M. [illegible]orcross	1	-	-1
Golf	-	7	+7
Tennis	-	7	+7
Triathlon/Marathon	1	-	-1
Hockey/Cricket	1	1	0
Action cricket	1	4	+3
Gymnastics	1	1	0
Baseball	-	1	+1
Jogging	-	2	+2
Cycle	-	2	+2
Skiing	1	1	0

Note: Subjects were participating in more than one sport pre-operatively (n = 25). Subjects were involved in a wider variety of sports post-operatively (n =39). The most significant decrease in post-operative participation occurred in soccer and rugby. The most significant increases occurred in golf, tennis, cricket, jogging and cycling i.e. from contact to non-contact sports.

It is not possible to work out a percentage in this table e.g. no subjects participated in golf pre-operatively but seven subjects played golf post-operatively.

4.9 Level of participation

Table 4.7

Level of participation			
Level	Pre-Operative (%)	Post-Operative (%)	Change
Social	4 (20%)	13 (65%)	+9
League	12 (60%)	5 (25%)	- 7
Provincial	4 (20%)	1 (5%)	- 3
No sport		1 (5%)	+1

Thirteen (65%) of subjects played sport socially post-operatively (compared to 20% pre-operatively). League participation dropped by seven subjects and provincial participation by three subjects.

Of the 20 subjects, three (15%) were playing the same level of the same sport, five (25%) were playing the same sport but at a lower intensity and eleven (55%) were participating in different sports. One subject (5%) was not participating in any sports activity.

4.10 Return to activity

All subjects involved in contact sports were advised not to return to that sport post-surgery by their surgeon, because of the increased risk of re-injury.
This advice did not stop four subjects from returning to soccer, although none returned to rugby.

Only eight subjects (40%) had returned to their preferred sport. Various reasons were given for the remaining 12 (60%) not returning to their preferred sport:

- seven (35%) made a conscious decision not to return to that sport due to fear of re-injury or lack of confidence in the knee;
- two (10%) stopped due to excess pain or knee problems;
- one (5%) stopped playing rugby as he felt that his knee would not be able to withstand sustained running;
- one (5%) could not find a suitable club;
- one (5%) stopped due to "giving way" while playing soccer (he no longer participated in any sport.

Five subjects (25%) returned to sporting activity between 2½ - 6 months post-reconstruction. Twelve (60%) returned between 6 - 12 months and 3 (15%) returned 12 - 18 months after their operation. The single subject who returned to sport one year after his operation continued to have problems with "giving way" and had stopped all sport.

4.11 Bracing

Twelve (60%) were not using any supportive devices during sports activities. Seven (35%) were still using a derotation brace and one (5%) was using a knee guard.

4.12 Rehabilitation

All the subjects (100%) continued with physiotherapy post-operatively but for different lengths of time.

4.12.1 Duration of Physiotherapy (n = 20)

Table 4.8

Duration of Physiotherapy	Number (%)
Less than 6 weeks	3 (15%)
8 weeks	1 (5%)
12 weeks	3 (15%)
16 weeks	3 (15%)
20 weeks	2 (10%)
24 weeks	4 (20%)
Greater than 24 weeks	4 (20%)

Seven subjects (35%) claimed to have followed the physiotherapy programme very closely. Seven (35%) followed it most of the time while six (30%) admitted to only following it sometimes.

4.12.2 Reasons for stopping Physiotherapy (n = 20)

Table 4.9

Reason for stopping Physiotherapy	Number (%)
Physiotherapist said he could stop	7 (35%)
Subject felt exercises were no longer necessary	1 (5%)
Low motivation	1 (5%)
Not enough time	7 (35%)
Too expensive	4 (20%)

4.12.3 Subjective assessment of results (n = 20)

Table 4.10

Subjective assessment of results	Number (%)
Satisfied - knee normal	6 (30%)
Satisfied - knee improved but not normal	12 (60%)
Dissatisfied - improved but not enough	1 (5%)
Dissatisfied - no change	0
Dissatisfied - worse	1 (5%)

4.13 Re-injury

Three subjects (15%) had re-injured their knee since returning to sport, but the pain and/or swelling had lasted for less than 2 weeks and required no treatment. As the subjects did not seek medical attention at the time of re-injury it is difficult to ascertain if the ACL itself was injured. This must be borne in mind when comparing studies. One subject (5%) complained of a feeling of "giving way" rather than a re-injury, which lasted until the next day.

4.14 Function

4.14.1 Functional assessment

Subjects were asked to rate the intensity (slight, moderate, vigorous, highest level) at which they could perform four different levels of activity.

i.e 1) work, activities of daily living;
2) light agility e.g. jogging, running;
3) heavy agility e.g. skiing, tennis;
4) jumping, pivoting, hard zigzagging e.g. rugby, soccer.

4.14.1 Functional assessment (n = 20)

Table 4.11

a)

Function	Intensity (demands on the knee joint)	Number (%)
1. Work, ADL	Moderate	1 (5%)
	Vigorous	2 (10%)
	Highest	17 (85%)
2. Light Agility	Slight	1 (5%)
	Moderate	3 (15%)
	Vigorous	7 (35%)
	Highest	9 (45%)
3. Heavy Agility	Slight	0
	Moderate	2 (10%)
	Vigorous	5 (25%)
	*Highest	8 (40%)
	Don't do	5 (25%)
4. Jump, Pivot, Hard Zig-zag (Rugby,soccer)	Slight	1 (5%)
	Moderate	1 (5%)
	Vigorous	2 (10%)
	Highest	2 (10%)
	Don't do	14 (70%)

*e.g. eight subjects could/were performing heavy agility activities at the highest level i.e. without any problems or limitations.

4.14.2 Work Capacity

The subjects were asked to rate their ability to work since their reconstruction. This was done to see if the subject could function "normally" at work following their reconstruction and if their knee limited their work capacity. Certain jobs impose more demands on the knee and would therefore influence work capacity.

One (5%) subject could only function at 25% of his pre-injury level (a tour operator with a quadriceps deficit of 41%). Four subjects (20%) - a bank clerk, technician, draughtsman and electrician - could function at 75% of their pre-injury level. Two subjects (10%) were able to work at 75% - 100% of their pre-injury level (a salesman and a director). Thirteen subjects (65%) were working maximally. Their occupations were :- engineer, manager (x 3), motor assembler, tool and die maker, chemist, technician, attorney, consultant (x 2), auditor and a self employed businessman.

4.14.3 Functional rating

Subjects were asked to rate the function of their injured knee at three different stages :

4.14.3.1 pre-injury;

4.14.3.2 pre-operatively;

4.14.3.3 at follow-up.

A rating scale of 0-10 was used where 0 = worst function and 10 = full function.

4.14.3.1 Pre-injury

- seventeen (85%) rated their knee function as 10 out of 10.
- three (15%) rated their function as 9 out of 10 (due to previous minor injury resulting in occasional symptoms).

The average pre-injury score was 9,85 out of 10.

4.14.3.2 Pre-operative rating of function

Table 4.12

Pre-operatively	
Number of subjects (n = 20)	Rating (out of 10)
1 (5%)	0
8 (40%)	1
4 (20%)	2 - 2,5
3 (15%)	3 - 3,5
3 (15%)	4 - 4,5
1 (5%)	5 - 5,5

The average score following injury was 2,38 (out of a rating of 10).

4.14.3.3 Functional Rating at follow- up (12 - 48 months post-operatively)

Table 4.13

At follow up:	
Number of subjects (n = 20)	Rating (out of 10)
1 (5%)	4
1 (5%)	5
4 (20%)	6
3 (15%)	7 - 7,5
4 (20%)	8
4 (20%)	9
3 (15%)	10

The average score at follow-up was 7,7 (out of a rating of 10).

Therefore, the average subjective rating score increased from the time of injury to follow- up by 5,32 (out of a rating of 10).

4.14.4 Intensity Level during ADL and at highest intensity

Subjects were asked to subjectively rate the severity (none, slight, moderate, severe) of specific symptoms at two different levels of activity;

a) during normal activities of daily living;

b) during their highest level of sport;

1) swelling;

2) pain;

3) apprehension;

4) giving way;

5) locking

This information was then compared to objective signs and symptoms and especially to their rating of their function and outcome of surgery to see if the results were comparable.

4.14.4 Severity of symptoms during ADL and activity

Table 4.14

	Activities of daily living		Highest intensity of sporting activities	
Symptom	Severity of symptoms	Number (%)	Severity of symptoms	Number (%))
1. Swelling	None	20(100%)	None Slight	19 (95%) 1 (5%)
2. Pain	None Slight Moderate	18 (90%) 1 (5%) 1 (5%)	None Slight Moderate Severe	10 (50%) 6 (30%) 3 (15%) 1 (5%)
3. Apprehension	None	20(100%)	None Slight Moderate Severe	5 (25%) 7 (35%) 7 (35%) 1 (5%)
4. Giving Way	None Slight	19 (95%) 1 (5%)	None Slight Moderate Severe	15 (75%) 2 (10%) 0 (0%) 3 (15%)
5. Locking	None	20(100%)	None	20(100%)

4.14.5 Functional activity

Subjects were asked if they experienced ANY functional disabilities during the following activities :-

i.e. 1) Walking
2) Squatting
3) Up stairs
4) Down stairs
5) Running
6) Zigzagging
7) Jumping

They were also requested to state at what intensity of the activity the disability occurred i.e. -

a) during activities of daily living e.g. for a short period or once off;

b) during their highest level of activity i.e. vigorously.

If they did not perform the activity they were asked to state the reason.

4.14.5 Functional disabilities during different activities

Table 4.15

	Activities Of Daily Living		**Highest Level of activity or during sport**	
Activity	Intensity	Number (%)	Intensity	Number (%)
1.Walking	None Slight Moderate	19 (95%) 1 (5%)	None Slight Moderate	15 (75%) 4 (20%) 1 (5%)
*2. Squat	None Slight Moderate Severe	17 (85%) 0 1 (5%) 2 (10%)	None Slight Moderate Severe	7 (35%) 3 (15%) 5 (25%) 5 (25%)
3. Up stairs	None Slight Moderate Severe	19 (95%) 1 (5%)	None Slight Moderate Severe	14 (70%) 5 (25%) 0 1 (5%)
4. Down stairs	None Slight Moderate	20(100%)	None Slight Moderate	12 (65%) 5 (25%) 3 (15%)
5. Running	None Slight Moderate Severe	19 (95%) 1 (5%)	None Slight Moderate Severe	10 (50%) 4 (20%) 5 (25%) 1 (5%)
6. Zig-zag	None Slight Moderate Severe Don't do	12 (60%) 5 (25%) 0 1 (5%) 2 (10%)	None Slight Moderate Severe Don't do	5 (25%) 6 (30%) 4 (20%) 3 (15%) 2 (10%)
**7. Jump	None Slight Moderate Severe Don't do	15 (75%) 1 (5%) 1 (5%) 0 3 (15%)	None Slight Moderate Severe Don't do	7 (35%) 4 (20%) 4 (20%) 2 (10%) 3 (15%)

*e.g.1. If the subjects had to squat/bend down once in their normal daily routine 17 would have no problem, one would have moderate difficulty and two would have severe functional problems. If the subjects were asked to squat repeatedly, seven would have no problems, three would have a slight problem, five would have moderate difficulties and five would have severe functional problems.

**e.g. 2. If the subjects had to jump once (e.g. off another object) during their normal daily routine, 15 would have no problems., one a slight problem and one a moderate problem. Three subjects do not jump within their normal daily routine. If they had to jump repeatedly, seven would be fine, four would have slight difficulty, four moderate difficulties and two severe difficulties. Three did not/would not be able to jump repeatedly.

4.15 Physical examination

4.15.1 Function

4.15.1.1 Sideways hopping (n = 20)

Table 4.16

Ability to Hop	Operated leg Number (%) (n = 20)	Unoperated leg Number (%) (n = 20)
Unable	2 (10%)	0
Difficult	8 (40%)	2 (10%)
Moderate	2 (10%)	2 (10%)
Easy	8 (40%)	16 (80%)

4.15.1.2 Squat on 1 leg (on the operated leg) (n = 20)

Table 4.17

Squat on 1 leg	Number	(%)
Unable	7	(35%)
Difficult	6	(30%)
Moderate	1	(5%)
Easy	6	(30%)

Eighteen (90%) could do a one legged squat on the unoperated leg and the other two subjects were unable to squat.

4.15.1.3 Duck Squat (n = 20)

Table 4.18

Duck Squat	Number	(%)
Unable	3	(15%)
Difficult	3	(15%)
Moderate	0	
Easy	14	(70%)

Note: Since squatting requires the use of both legs, it is not possible to compare one leg to the other.

4.15.1.4 Running

The subjects times were recorded and compared to 20 active males, aged 20 - 35 years, without any knee problems.

4.15.1.4 (a) Run there and back (5m distance five times) (n = 20)

Table 4.19

Time (s)	Number (%)
16 - 20	16 (80%)
21 - 25	4 (20%)

The range of the subjects times varied from 16,64 seconds to 23,30 seconds (average = 18,97 seconds). The times of the controls ranged from 16,71 seconds to 23,34 seconds (average = 18,25 seconds).

4.15.1.4 (b) Run in figure of eight (five times) (n = 20)

Table 4.20

Time (s)	Number (%)
20 - 24	6 (30%)
25 - 29	14 (70%)

The range of the subjects times varied from 20,24 seconds to 28 seconds (average = 24,42 seconds). The times of the controls ranged from 21,24 seconds to 26,05 seconds (average = 22,8 seconds).

4.15.1.4 (c) Zigzag running (n = 20)

Table 4.21

Time (s)	Number (%)
31 - 35	8 (40%)
36 - 40	2 (10%)
41 - 45	9 (45%)
46 - 50	0
51 - 55	1 (5%)

The times of the subjects ranged from 31,57 seconds to 51,30 seconds (average = 39,64 seconds). The times of the controls ranged from 35,47 seconds to 41,5 seconds (average = 39,23 seconds).

4.15.2 Range of Movement

4.15.2.1 Extension (n = 20)

Table 4.22

Extension Range	Operated leg (%)	Unoperated leg (%)
- 4° hyperextension	0	2 (10%)
- 2°	2 (10%)	5 (20%)
0°	10 (50%)	11 (55%)
2°	1 (5%)	2 (10%)
3°	4 (20%)	
5°	2 (10%)	
10°	1 (5%)	

Therefore eight subjects (40%) lacked 2° or more of extension on the operated knee. Two subjects lacked 2° extension on their unoperated knee. The average range of extension was 1,5° on the operated knee and -0,7° on the unoperated knee, i.e. slight hyperextension.

4.15.2.2 Flexion (n = 20)

Table 4.23

Range	Operated leg (%)	Unoperated leg (%)
120°	2 (10%)	0
125°	3 (15%)	3 (15%)
127°	2 (10%)	0
128°	3 (15%)	2 (10%)
130°	6 (30%)	7 (35%)
132°	2 (10%)	2 (10%)
135°	1 (5%)	5 (25%)
140°	1 (5%)	1 (5%)

Therefore, 10 subjects (50%) had less than 130° flexion, but five unoperated knees also had less than 130°. The average range of flexion on the operated knee at follow-up was 129° and 131° on the unoperated knee.

4.15.3 Sagittal translation

4.15.3.1 Lachman test (n = 20)

Table 4.24

Side-to-side difference	Number (%)
0mm	4 (20%)
1mm	7 (35%)
2mm	6 (30%)
3mm	0
6mm	1 (5%)
-1mm	1 (5%)
-2mm	0
-3mm	1 (5%)

Negative value indicates the unoperated knee to be tighter than the operated knee. Therefore, 19 subjects (95%) had a side-side difference less than or equal to 3mm (including the two tighter knees). The average side-to-side difference was 1,05mm. The student t- test = 2,76 which was significant (p = 0,05). The t- test determines whether or not a significant difference exists between the means of two small samples (in this study, the operated leg and the unoperated leg (Allan, 1982).

4.15.3.2 Anterior drawer test (n = 20)

Table 4.25

Side-to-side difference	Number (%)
0 mm	6 (30%)
1 mm	2 (10%)
2 mm	5 (25%)
3 mm	2 (10%)
4 mm	1 (5%)
7 mm	1 (5%)
-1 mm	1 (5%)
-2 mm	2 (10%)

Therefore, 18 subjects (90%) had less than or equal to 3mm side-to-side difference (including the three tighter knees). The average side-to-side difference was 1,10 mm. The student t- test= 2,72 which was significant (p = 0,05).

4.15.3.3 End Point

Nineteen (95%) had a firm end point while one (5%) had a semi-solid end point. The subject with the semi-solid end point correlated to the side-to-side difference of 7mm on anterior drawer testing and 6mm on Lachman testing.

4.15.4 Pivot Shift

Twelve (60%) had no pivot shift, seven (35%) had a mild pivot shift i.e. pivot glide and one (5%) a moderate pivot shift.

4.15.5 KT 1000

4.15.5.1 Manual Reading at 20lb (89N) (n = 20)

Table 4.26

Side-to-side difference	Number (%)
Equal	1 (5%)
1 mm	2 (10%)
2 mm	4 (20%)
3 mm	2 (10%)
4 mm	3 (15%)
5 mm	2 (10%)
7 mm	1 (5%)
-1 mm	3 (15%)
-3 mm	1 (5%)
-4 mm	1 (5%)

Therefore, 13 subjects (65%) had a 3mm or less side-to-side difference (including the four tighter knees). The average side-to-side difference at 20 pounds was 1,75mm. The student t-test = 2,698 which was significant (p = 0,05).

4.15.5.2 Manual maximum test (n = 20)

Table 4.27

Side-to-side difference	Number (%)
Equal	5 (25%)
1 mm	1 (5%)
2 mm	2 (10%)
3 mm	4 (20%)
4 mm	1 (5%)
5 mm	1 (5%)
6 mm	1 (5%)
9 mm	1 (5%)
-1 mm	2 (10%)
-3,5 mm	1 (5%)
-4 mm	1 (5%)

Therefore, 14 subjects (70%) had 3mm or less side-to-side difference at manual maximum testing (including the two tighter knees). The average side-to-side difference was 1,58mm. The student t-test = 2,488 which was significant (p = 0,05).

4.15.6 Varus & Valgus

All 20 subjects had 0-5mm (grade 1) displacement on varus and valgus testing at 0° extension and 25° flexion.

4.15.7 Quadriceps girth

A positive value indicates the operated leg to have the bigger girth, a negative value indicates the unoperated leg to have the larger circumference.

4.15.7.1 Midpatella measurements (n = 20)

Table 4.28

Midpatella	Number (%)
Equal	12 (60%)
0 to -1cm	7 (35%)
1cm	1 (5%)

4.15.7.2 5 cm above superior pole of the patella (n = 20)

Table 4.29

5cm above superior pole	Number (%)
-2,5 to -3cm	1 (5%)
-1,5 to -2cm	5 (25%)
-0,5 to -1cm	6 (30%)
Equal	5 (25%)
0,5cm	1 (5%)
1cm	1 (5%)
2,5cm	1 (5%)

4.15.7.3 10 cm above superior pole of the patella (n = 20)

Table 4.30

10cm above superior pole	Number (%)
-2,5 to -3cm	1 (5%)
-1,5 to -2cm	7 (35%)
-0,5 to -1cm	4 (20%)
Equal	5 (25%)
0,5 to 1cm	1 (5%)
1,5 to 2cm	1 (5%)
2,5 to 3cm	1 (5%)

4.15.8 Patellofemoral joint

4.15.8.1 Patellofemoral joint movement (n = 20)

Table 4.31

Movement		Number (%)
Transverse :	Increased	5 (25%)
	Normal	11 (55%)
	Decreased	4 (20%)
Longitudinal :	Increased	0
	Normal	18 (90%)
	Decreased	2 (10%)

4.15.8.2 Crepitus - eight (40%) subjects had no crepitus while 12 (60%) had mild crepitus.

4.15.8.3 Pain - sixteen (80%) had no pain in the patellofemoral joint while three (15%) had mild pain behind the patella and one (5%) moderate pain behind the patella. This correlates to the subjects previous preceptions of their pain and the site thereof.

4.15.8.4 Instability - no subjects complained of instability of the patellofemoral joint.

4.15.9 Medial and lateral compartments

4.15.9.1 Medial compartment - eighteen subjects (90%) had no crepitus while two (10%) had mild crepitus. No subjects complained of tenderness and all were negative on McMurray testing.

4.15.9.2 Lateral compartment - one subject (5%) had mild crepitus. Only two (10%) complained of lateral, mild tenderness. McMurray testing was negative in all 20 subjects.

4.15.10 Cybex isokinetic testing

The values to be assessed were defined as (repeated in Materials and Methods - see page 85) :

i) Peak torque = the single highest point of the graph, regardless of where in the range it occurs (Davies, 1992); and indicates maximum muscular tension capability.

ii) Average power = total work (i.e. total area under the torque graph) divided by the time it takes to perform the work (Davies, 1992);

iii) Endurance ratio = the ratio that occurs as the muscle exercises and fatigues. A certain number of repetitions are compared at the beginning and end of the test and the percent change is calculated (Davies, 1992). In this test of 30 repetitions, the work done in the last 20% of the set is divided by the work done in the first 20% of the set and then multiplied by 100.

Results of Cybex isokinetic testing (see 4.15.10 page 112)

Table 4.32

Muscle	Values	Speeds	Range of Deficits	Average deficit
Hamstrings	Peak torque	60°/s	-19% to 25%	5,95%
		180°/s	-18% to 13%	0,25%
		240°/s	-26% to 25%	1,70%
	Peak torque to % body weight	60°/s	-8% to 17%	3,60%
		180°/s	-6% to 8%	0,75%
		240°/s	-9% to 12%	1,00%
	Power	60°/s	-19% to 27%	4,60%
		180°/s	-16% to 21%	4,15%
		240°/s	-30% to 26%	1,15%
	Endurance	240°/s	-21% to 9%	-4,00%
Quadriceps	Peak torque	60°/s	-2% to 41%	15,95%
		180°/s	-15% to 23%	7,90%
		240°/s	-15% to 23%	7,15%
	Peak torque to % body weight	60°/s	-3% to 37%	14,90%
		180°/s	-8% to 16%	5,85%
		240°/s	-7% to 13%	4,25%
	Power	60°/s	-2% to 33%	11,05%
		180°/s	-26% to 27%	7,15%
		240°/s	-1% to 29%	8,30%
	Endurance	240°/s	-16% to 11%	-3,75%

Note: The negative value indicates the operated knee to be stronger than the unoperated knee.

Mean Values for Strength, Power and Endurance on Cybex Testing (p = 0,05)
Table 4.33

MUSCLE	MEAN.VARIABLE	SPEED	OPERATED KNEE MEAN VALUE	UNOPERATED KNEE MEAN VALUE	t VALUE	SIGNIFICANCE
Hamstrings	Mean peak torque (strength)	60°/s 180°/s 240°/s	90,45% 80,40% 65,80%	96,75% 80,85% 67,15%	t = 1,067 t = 0,03 t = 0,34	Not significant Not significant Not significant
	Mean power	180°/s	198,90%	207,40%	t = 0,83	Not significant
	Mean endurar.	240°/s	49,90%	45,90%	t = -1,49	Not significant
Quadriceps	Mean peak torque (strength)	60°/s 180°/s 240°/s	144,40% 113,90% 93,35%	173,35% 124,45% 102,55%	t = 2,85 t = 1,35 t = 1,10	Significant Not significant Not significant
	Mean power	180°/s	274,60%	297,7%	t = 1,3	Not significant
	Mean endurance	240°/s	56,40%	52,70%	t = -1,64	Not significant

Comparison of results of acute reconstructions versus chronic reconstructions

Table 4.34

	Acute (n=10)	Chronic (n=10)
Pain	8	6
Outcome satisfied	9	9
Return to preferred sport	5	3
Range of movement	2 lost extension 4 less than 130° flexion	6 lost extension 6 less 130° flexion
Lachman side-to-side difference > 3mm	0	1
Anterior Drawer side-to-side difference > 3mm	0	1
KT1000 (20lbs) side-to-side difference > 3mm	2	5
KT1000 (maximum manual) side-to-side difference > 3mm	2	4
Average side-to-side difference on Lachman testing	Average = 1,3mm	Average = 0,8mm
Average side-to-side difference on Anterior Drawer testing	Average = 1,2mm	Average = 1,2mm
Average side-to-side difference on KT1000 testing at 20lbs	Average = 1,6mm	Average = 1,85mm
Average side-to-side difference on KT1000 testing (maximum manual)	Average = 1,7mm	Average = 1,65mm
Stiffness	4	4
Muscle weakness	8	5
Giving way	3	3
Pivot glide/shift	3	3

5.0 DISCUSSION

The five questions posed in the introduction will be addressed (see objectives of this study, page 4).

5.1 Subjective outcome

5.1.1 Is the subject satisfied with the surgical outcome?

5.1.2 Does the subject think undergoing surgery was worthwhile?

These two questions are related and are therefore discussed together. The answer is definitely yes. Eighteen subjects (90%) were satisfied with their knee. Only two were dissatisfied although one felt his knee had improved since his operation but not as much as he would have liked. Of the 16 (90%) satisfied subjects, six (30%) felt their knee was normal. Of the two patients who were dissatisfied with their outcome, one would still recommend the reconstruction to other patients while the other would not. The subject who would not recommend the reconstruction may have had a coloured view as his medical aid/medical insurance had not paid for his surgery and he was non-compliant with rehabilitation.

In this study six subjects (30%) felt their knee was normal. In studies where this specific question was asked, Johnson et al's study (1984) found only 7% felt their knee to be normal; Clancy et al, (1982) stated that 12% felt their knee to be normal; while Tibone & Antich, (1988) found 27,3% to have normal knees. Aglietti et al, (1992) found 32% of their subjects to have normal knees. The subjects satisfaction with their surgical outcome compares very favourably to other studies.

In this study, twelve subjects (60%) felt their knee had improved post-operatively but was still not normal. Again, this compares favourably to other studies e.g. Johnson et al, (1984) found 64% to have improved knees; Tibone & Antich, (1985) 72,7% improvement.

The overall subjective satisfaction in this study (18 subjects = 90%) is similar to other studies e.g. Clancy et al, (1982) 96% satisfaction; Bartlett & Crowe, (1985) 96% satisfaction; O'Brien et al, (1991) 93% satisfaction and Howe et al, (1991) 92% satisfaction.

The outcome of the operation can be correlated to the subjective and functional results (Johnson et al, 1984; Noyes et al, 1991). The two subjects who were dissatisfied had more residual symptoms and poorer functional results. Conversely subjects who felt their knee was normal had hardly any subjective complaints and better functional results.

A possible reason for the one subject's perception for the operation not being worthwhile was that his medical aid/medical insurance had not paid for his reconstruction and that his knee function had only marginally improved. His lack of satisfaction may have been affected by his poor rehabilitation as he attended physiotherapy for less than six weeks and had a 41% quadriceps strength deficit at follow-up. The other subject who complained that his knee was worse attended physiotherapy for less than eight weeks and functional activities (e.g. running, walking, going downstairs) were problematic for his operated knee. This is not surprising as he had a 36% quadriceps deficit.

Many authors (Shelbourne et al, (1991); Wasilewski et al, (1993); Mohtadi et al, (1991) have commented on the timing of reconstruction on the outcome of surgery. Wasilewski et al, (1993) found acute semitendinosus reconstruction recovery to be significantly slower than subacute or chronic reconstructions in most measured parameters of return of motion and strength gain. Shelbourne et al, (1991) found that contrary to initial belief, delaying surgery at least three weeks after injury instead of immediate surgical intervention achieved better results. The reasons for their findings were multifactorial. Within the first week post-injury, the acutely torn ACL knee has limited range of motion, a moderate haemarthrosis and quadriceps inhibition. At three weeks from injury the acutely injured ACL knee begins to behave like a chronic ACL deficient knee without the irreparable damage of the chronically unstable knee. The authors also observed psychological changes in the athlete during this delay resulting in an improved attitude towards reconstruction and rehabilitation. Ultimately, delaying surgery at least three weeks after injury resulted in a

decreased incidence of arthrofibrosis (limited range of motion, particularly terminal extension). Mohtadi et al, (1991) found an increased incidence of restricted range of movement in patients who had surgery less than two weeks after injury. Conversely, Wilcox & Jackson, (1987) believe that surgical reconstruction of an acute ACL rupture within seven to ten days is essential to obtain the best results, especially in the athlete who wishes to return to a competitive level of participation. Wilcox & Jackson do not give reasons for their opinions.

In this study, no trend became apparent due to the small population of the two subjects who were dissatisfied. One had his reconstruction at three weeks while the other had his two years after his initial injury.

Acute reconstructions were defined as less than six weeks between injury and reconstruction, subacute were 6 - 12 weeks and chronic were reconstructions performed 12 weeks or more after injury. The acute and subacute groups were grouped together, thus the range of acute and subacute reconstructions were four days to three months. In this study the chronic reconstructions were performed five months to 60 months post-injury.
(see table 4.34 page 115).

Strum et al, (1990) found a 35% incidence of arthrofibrosis in acute reconstructions and repairs compared to 12% in the chronic group. These patients had difficulty regaining movement and persistent synovial thickening of the suprapatellar and infrapatellar areas together with decreased patella mobility and often retropatellar crepitus. Early repeat arthroscopy and manipulations of the knee joint helped to treat this complication. Arthofibrosis, if treated early had no deleterious effect on the final clinical outcome.

Chronic ACL deficient knees usually have varying degrees of associated capsular laxity as well as intra-articular damage to the menisci and articular surfaces as a result of the original injury or recurrent subluxations. The potential results are affected by the degree of degenerative arthritic changes present before surgical intervention (Wilcox & Jackson, 1987). Prior damage cannot be reversed. Patellofemoral pain or compartmental pain may

not be alleviated if they are the result of altered joint mechanics and/or degenerative cartilage changes (Johnson et al, 1984).

In this study the natural history of the chronically ACL deficient knee may have contributed to the poor result of the dissatisfied, chronically reconstructed subject. The three week interval between injury and reconstruction in the other dissatisfied subject, may have been too short a time period for post-injury symptoms to resolve e.g. pain, effusion.

The results of surgery on the acute and chronic groups are similar in this study (see table 4.34 page 115).

A review of table 4.34 (page 115) reveals more subjects undergoing acute reconstructions to have post-operative pain (eight acute versus six chronic) reconstructions and muscle weakness (eight acute versus five chronic reconstructions). More subjects undergoing acute reconstructions had returned to their preferred sport (five acute versus three chronic). The most notable differences in the chronic group occurred in range of movement and side-to-side differences on KT1000 testing. Six subjects undergoing chronic reconstruction had lost extension while only two subjects in the acute group lost extension. Flexion was more comparable - six chronic subjects lost flexion while four in the acute group lost flexion. This limited range of motion may have been present pre-operatively. Unfortunately, no pre-operative range of motion data was available.

More subjects undergoing chronic reconstructions had a side-to-side difference greater than 3mm on KT1000 testing (five on testing at 20 pounds and four on maximum manual testing compared to two at 20lbs and two on maximum manual testing in the acute group).

5.1.3 Is the subject having residual symptoms?

Many subjects were still suffering from patellofemoral pain, muscles weakness or giving way.

Pain was the most commonly felt symptom, with 70% either having pain or discomfort. In this study the incidence of pain is high, but the duration is low. Eleven (40,7%) felt their pain on strenuous activities while four (14,8%) felt their pain with moderate activities. More than one factor could be responsible for their pain resulting in these percentages. Rest and/or cold weather accounted for the remainder of the subjects pain.

A review of the literature reveals the incidence of patellofemoral pain to vary between 14% (Johnson et al, 1984) and 80% (Rosenberg et al, 1992 and Wilk et al, 1994). Strenuous activities in Wilk et al's study (1994) resulted in pain in 52% of subjects which is comparable to the 40,75% in this study. Moderate activities provoked pain in 10% of Wilk et al's subjects which is comparable to the 14% in this study.

The most cited pain provoking factors in this study were kneeling and jumping (comparable to other studies) - (see table 4.2 page 87). The location of the pain was also comparable. (see table 4.3 page 88). No studies have commented on the duration of the provoked pain. (see table 4.5 page 88). Although 70% of subjects experienced pain in this study, it was usually momentary or lasted less than 30 minutes. Only one subject complained of pain lasting longer than one day. In general, it would appear that provoked pain was of short duration in this study, which has not previously been investigated in the literature.

Although 14 subjects had complained of pain, 12 were still satisfied with their outcome indicating that pain was not necessarily linked to subjective outcome. Of the 14, six had returned to their preferred sport. Pain did not seem to be a major factor in their return to sport. A reason for this would appear to be that the subjects' pain was of short duration and not necessarily provoked during their preferred sporting activity. Of the 14 subjects who had pain, eight had not returned to their preferred sport.

Of the six subjects with no pain, four had not returned to their preferred sport either. Thus only two subjects with no pain had returned to their preferred sport. (See 5.2.1 and 5.2.2 return to sport page 127).

From the present results, it seems that pain seriously affects the function of the knee - the more painful the knee, the more functionally limited the subject. On analysis of hopping, one legged squat and duck squatting, both subjects who were unable to perform all three of these activities had pain. Subjects who had moderate difficulties with these activities also had pain. Pain was present in six subjects (of eight) i.e. 75% who found hopping difficult, four of six (66,6%) who found one-legged squatting difficult and one of three (33,3%) who found duck squatting difficult (See page 126).

Eighteen subjects were very satisfied and two dissatisfied with their surgical outcome despite the presence of occasional pain. The one subject who felt he was worse post-operatively had a 36% quadriceps strength deficit and the other dissatisfied subject a 41% strength deficit. This residual weakness could reflect their opinion of their outcome.

The second residual symptom was quadriceps atrophy or weakness.

Rosenberg et al, (1992) obtained quantitive data from computer tomography (CT) scans - these showed a persistent deficit in the cross sectional area of the quadriceps in all patients (n=10) at 10cm above the superior pole of the patella, with the mean deficit being 13%. This was statistically significant. The mean deficit of vastus medialis obliquus at 5cm above the superior pole of the patella was 13% (with a range of 5% - 30%) which was statistically significant. The hamstrings were essentially equal with 60% having an increased cross-sectional area on the involved extremity.

In their discussion they noted that girth measurements did not correlate well with the CT scan measurements or isokinetic testing results. Computer tomography scans demonstrated a disproportionate subcutaneous cross section in patients with equal girth but diminished quadriceps cross-sectional area.

In this study, 10cm and 5cm above the superior pole of the patella were used as measurement parameters (as in Rosenberg et al, 1992). Authors comment infrequently on thigh atrophy in the literature. Those who have commented use varying measurements which makes comparisons difficult.

The least noteworthy differences occurred in measurements around the mid-patella with the most noteworthy occurring at 10cm from the superior pole of the patella in this study.

In this study, the subject with the largest loss of girth (3cm at 10cm above the superior pole of the patella and 4cm at 5cm above the patella) did have the highest quadriceps strength deficit (41%). This association did not seem relevant in other subjects. e.g. the patient with a 36% quadriceps deficit had a 2cm circumference difference at 10cm but no difference at 5cm and at mid-patella level. Another subject who had no difference in circumference at 10cm, -1cm (i.e. greater on the operated leg) at 5cm and ½ cm at mid-patella still had a 14% quadriceps deficit and 7% hamstring deficit on Cybex isokinetic testing. Another subject had a 10% quadriceps deficit but had a larger girth on measurement. Thus, there does not seem to be a good association between thigh girth and isokinetic testing in this study.

It seems that there was an association between thigh atrophy, equal to or greater than 1cm and pain. This was only established at 10cm above the patella. Of the 14 subjects complaining of pain, eight had thigh atrophy equal to or greater than 1cm at 10cm above the patella. This confirms O'Brien et al's study (1991) where 83% of painful knees had more than 1cm of quadriceps atrophy.

No constant trend between a subjective feeling of muscle weakness and thigh circumference was apparent. Of the 12 subjects who complained of a sensation of muscle weakness, two actually had no differences in thigh girth and one even had a larger girth on the operated leg. The subject who complained of muscle weakness on the unoperated knee had half a centimetre girth difference at 10cm and at the mid-patella level. The other subjects' did have a deficit in girth especially at 10cm from the superior pole of the patella.

The average loss of girth at the level of the middle of the patella on the operated knee was 0,05cm (range --1cm to 0,5cm with the minus indicating the affected leg to have the larger circumference). The average loss of girth at 5cm from the superior pole of the patella was 0,5cm (range=-2,5cm to 4cm) and the average loss at 10cm, 0,6cm (range=-2,5cm to 3cm). This emphasises the fact that 5cm and 10cm above the superior pole of the patella are the most suitable measurements for quadriceps atrophy in this study.

At the level of the mid-patella, two subjects actually had a larger girth on the operated leg which could not be attributed to an effusion. All three levels of measurements on both subjects were larger on the operated side indicating a larger thigh circumference. The increase in girth could be due to an increase in cross-sectional area of the hamstrings and/or quadriceps or an increase in subcutaneous fat. It seems that as all subjects had undergone rehabilitation following their reconstruction, an increase in girth would be most likely due to this factor. One of these subjects had stronger hamstrings (by 19%) on the operated side and his quadriceps deficit was only 11% - his increase in hamstring strength could result in an increase in hamstring cross sectional area which would explain why the operated leg was larger in circumference. The other subject had a 5% hamstring deficit and a 15% quadriceps deficit on the operated leg. The reason for his increase in girth could be due to an increase in subcutaneous fat rather than an increase in muscle as he did weigh 230lbs.

Bach et al, (1994) found no correlation between thigh girth atrophy and knee flexion contractures, patellofemoral crepitation, functional tests or tighter post-operative KT1000 values on maximum manual testing.

5.1.3.1 Relationship between muscle weakness, isokinetic muscle strength testing and function

Variability of isokinetic testing in the literature is a problem because of the use of different machines (e.g. Cybex, Biodex or KinCom) and different speeds (e.g. 30° per second, 60° per second, 90° per second, 120° per second, 180° per second, 240° per second and 300° per second). The most commonly used speeds were 60° per second, 180° per second and

240° per second which were also used for this study. (See materials and methods, page 84).

Isokinetic exercise controls the speed at which the movement is performed (i.e. a constant speed) but varies the resistance. This variable resistance exercise accommodates fatigue and pain and maximally loads the muscle at every point in the range of motion and this accommodates fatigue and pain (Smith & Melton, 1981). The increased strength associated with isokinetic exercise has been attributed to the fact that an accommodating contraction enables one to do more work in the same period of time than is possible with either constant resistance or variable resistance (Smith & Melton, 1981).

When using the Cybex dynamometer, only concentric contractions are tested in both the quadriceps and hamstrings. Newer machines (e.g. KinCom) allow for eccentric testing.

Most studies e.g. Tibone & Antich, (1988), Shelbourne et al, (1990), Rosenberg et al, (1992), have shown that hamstring deficits are much less apparent at follow-up than quadriceps deficits which often persist. The same was found in this study as 12 subjects (60%) had a quadriceps deficit greater than 10% but only four (20%) had persistent hamstring deficits greater than 10% at follow-up.

The two subjects with the highest quadriceps deficits (41% and 36%) had the worst subjective opinions on the surgery. Both were dissatisfied and felt the operation was not worthwhile. The subject who had a 41% deficit had a range of movement of 10° - 125° only and complained of stiffness, muscle weakness and giving way. His lack of quadriceps strength could explain his subjective complaints of muscle weakness and giving way. He attended physiotherapy for less than six weeks which could also explain his persistent deficit. He had a pivot glide i.e. a mild pivot shift and 4mm side-to-side difference at 20lbs on KT1000 testing and 2mm side-to-side difference on maximum manual testing. (His lack of strength could also contribute to his persistent pain). This is evident due to the fact that of the seven subjects with greater than 20% quadriceps strength deficit, six experienced pain (see next paragraph).

The subject who had a 36% deficit had 0° - 120° of movement and also complained of stiffness, muscle weakness and giving way. He had a pivot glide i.e. mild pivot shift and complained of patellar pain. Side-to-side testing showed him to be 1mm tighter (using the KT1000) and 2mm more on Lachman testing. This is an unusual result, the reason for which is not apparent. Therefore it would appear that a residual quadriceps weakness affects the outcome of the reconstruction in this study.

Of the 12 subjects (n=20) who complained of a subjective feeling of muscle weakness (including one on the unoperated knee), seven had a quadriceps deficit greater than 20%. On the other hand, if a deficit of 10% is used, 12 would have a difference. Of those seven subjects with greater than 20% quadriceps deficit, six complained of pain. Of the 12 patients with greater than 10% deficit, 11 complained of pain. Thus, there seems to be a association between quadriceps weakness and knee pain. Four of the 12 subjects with greater than 10% deficits had returned to their preferred sport (their deficits ranged from 15% to 27%) of whom only one was participating at the same pre-injury level.

Of the remaining eight (n=20) who did not complain of a subjective difference in muscle strength, only two had a quadriceps deficit greater than 10%. Of those eight, four had returned to their preferred sport (two acute reconstructions and two chronic reconstructions). Four of those eight subjects complained of pain or discomfort (two acute and two chronic reconstructions). Of the four subjects complaining of pain or discomfort, three had returned to their preferred sport.

The timing of the reconstruction did not have a major effect on muscle weakness. In this study, of the 12 subjects with greater than 10% quadriceps deficit six were acute and six were chronic. The acute group averaged a 12,2% deficit (range 15% - 36%) while the chronic group averaged a 10% deficit (range 11% - 41%). Of these 12, only four had a persistent hamstring deficit greater than 10% (two acute reconstructions and two chronic reconstructions). Another two subjects also had a hamstring deficit greater than 10% but not a quadriceps deficit greater than 10%. Therefore, a total of six subjects (out of 20) had a hamstring deficit greater than 10% in this study (three acute and three chronic). The

acute group averaged a 16,3% hamstring strength deficit while the chronic group averaged a 20% strength deficit.

There seems to be a relationship between quadriceps deficit and function. Of the seven subjects who had a 20% or greater deficit, six had functional difficulties and six had pain.. Only one found all three activities easy to perform and had no pain. Although this subject had a 21% quadriceps strength deficit, he had no pain which could explain why he found all three activities easy to perform (see table 5.1 page 126).

Quadriceps Deficit relating to functional activities

Table 5.1

		Activities		
Pain	Quadriceps Deficit	Hopping	1 Leg Squat	Duck Walk
Yes	41%	Difficult	Unable	Difficult
Yes	36%	Unable	Unable	Unable
No	27%	Moderate	Difficult	Easy
Yes	27%	Difficult	Difficult	Easy
Yes	26%	Difficult	Unable	Unable
No	21%	Easy	Easy	Easy
Yes	20%	Difficult	Unable	Easy

Note: From the above table, as the quadriceps deficit becomes less the activities become marginally easier to perform.

Wilk et al, (1994) found a positive correlation between isokinetic knee extension peak torque and subjective knee scores. Sachs et al, (1989) stated that patients with weaker thigh musculature demonstrated poorer scores on the hop test.

Giving way can occur for two reasons - muscle weakness or anterolateral laxity. Of the six subjects complaining of giving way, five (83,3%) had a quadriceps strength deficit of greater than 13%. The other subject's quadriceps was 1% stronger on the operated knee. The subject who complained of giving way with moderate activity had a quadriceps deficit of 36%. In this instance, muscle weakness is likely to be the cause of giving way. Only two of these five subjects had a side-to-side difference of greater than 3mm. On KT1000 testing at 20lbs, one of these two subjects was "tighter" on the operated side.

One subject experienced giving way while playing soccer. He gave up soccer and his knee no longer gave way. His side-to-side difference on Lachman testing was 6mm and KT1000 testing at 20lbs revealed a side-to-side difference of 7mm. A moderate pivot shift was present. His quadriceps strength deficit at 60°/s was only 10%. His giving way can be attributed to anterolateral laxity rather than muscle weakness.

In this study, muscle weakness seems to be the major contributing factor to giving way. Only in one subject was giving way due to a biomechanical abnormality.

The incidence of giving way (30% in this study is higher than that indicated in the literature (e.g. Shelbourne et al, 1990 - 7%; Howe et al, 1991 - 5%). Wilk et al (1994) reported that 23% of patients complained of giving way with strenuous activities in their study which is comparable to this study. It must be pointed out that most subjects in their study could not recall an actual incident of giving way but rather a feeling of giving way instead.

5.2 Return to sport

5.2.1 Has the subject returned to his preferred sport; and
5.2.2 Is the subject playing the same sport at the same pre-injury level?

Before injury, all subjects were participating in sporting activities. Some were involved in more than one sport, although most seemed to concentrate on one specific sport before their injury. After the reconstruction, patients were participating in a wider variety of sports at

a lesser intensity.

Nineteen subjects had returned to sporting activity (95%). One subject was not participating in any sport due to giving way. Only three of the subjects (15%) had returned to the pre-injury level of their preferred sport while five (25%) were playing the same sport but at a lower level.

Of the 12 subjects who had not returned to their preferred sport, only three (25%) had experienced actual problems with their knee when trying to return to sport. One subject had excessive pain (he participated in rugby previously), one complained of giving way during soccer and the other had varying knee problems e.g. pain, swelling and was not able to return to soccer. All three were involved in contact sports and would have been advised to change sports.

The most common cause of ACL injury in this study was rugby and soccer i.e. contact sports. The main reason for the low return to pre-injury level in this study was the subjects being advised to change their sport by the surgeon. Fifteen subjects were advised to change sports by their surgeon (11 soccer players, three rugby players and one squash player). Four soccer players returned to soccer despite their surgeon's advice. Therefore, 11 subjects took their surgeon's advice and did not return to their preferred sport. Of these 11, one complained of giving way during soccer, one experienced problems with his knee, one had excess pain, another lacked confidence in the knee and the other was afraid of re-injuring his knee. Thus, five subjects had other reasons (as mentioned above) for not returning to their preferred sport besides the surgeon's advice.

The other reason given for not returning to their preferred sport was not being able to find a suitable club.

Thus, 15 out of 20 (75%) subjects were advised to change sports. Eleven out of 20 (55%) took their surgeon's advice. The low return to pre-injury sport in this study is due to this factor.

Analysing return to sport data must include the pre-injury sport and level of participation for the results to have meaning.

These figures for return to pre-injury sport are lower than in other studies. Bartlett & Crowe, (1985) found 78% of subjects returned to vigorous sport (only percentages were given in this study). Johnson et al, (1984) reported that 25,3% returned to sport as normal; 43,7% made some modifications; 23% were involved in light sports and 8% found sport impossible. Elmquist et al, (1988) reported 29% returned to their pre-injury level, while Tibone & Antich, (1988) reported that six (55%) returned to pre-injury level (but there were only 11 subjects), four (36%) limited their sporting activities and one (9%) were unable. Kaplan et al, (1991) reported that 75% of subjects returned to strenuous sports and 92% to less strenuous sports.

The main reason for the disparity in this study is the recommendation of the surgeon to change sports. Of the 14 players involved in rugby and soccer pre-injury, only four returned to soccer post-operatively (none to rugby). Post-operatively the biggest increase in participation occurred in golf (an increase of seven subjects), tennis (an increase of seven subjects) and squash (an increase of six subjects). These increases can be explained by the fact that subjects were advised not to return to contact sports.

Another reason for the low return to sport could be the original pre-injury level of activity. No subjects were playing sport at a national level. Four subjects (20%) were playing provincial sport before injuring their knee. Only one subject (5%) returned to this level post-operatively. Sportsmen competing at "higher" levels of activity i.e. provincial or national levels could be more motivated to return to their pre-injury level.

The level of participation also decreased after the reconstruction (as well as the number of subjects returning to sport). Many more subjects were playing social sport (an increase of nine subjects) than league (a decrease of seven subjects) and provincial sport (a decrease of three subjects) - see table 4.7 page 91).

Glasgow et al, (1993) found that an early return to activity did not predispose patients to re-injury or less satisfactory results. In this present study, two subjects returned to sport two months post-operatively. Although neither subject had returned to their preferred sport, one subject was very satisfied with his outcome and had no side-to-side difference on Lachman or KT1000 testing. The other subject was dissatisfied with his outcome but he was driving within two weeks and running at approximately six weeks. The loading of his knee so soon post-operatively could probably have affected his stability and function. The dissatisfied subject also had a 41% quadriceps deficit at follow-up and 4mm side-to-side KT1000 difference which confirms this would have affected his return to sporting activities.

In this present study, of the eight patients who returned to their preferred sport, none returned before nine months. The average interval for return to their preferred sport was 12 months (range 9 - 15 months). Thus, it may be that a return to preferred sport may be more successful if attempted 9 - 12 months post-operatively. Subjects having an ACL reconstruction now, may be advised by their surgeon that they will be able to return to sporting activity within 9 - 12 months and some orthopaedic surgeons may advocate six months if the subjects follow an accelerated rehabilitation programme.

5.2.3 Is the subject wearing a brace for sport?

Although most researchers investigate the return to sport, very few comment on bracing.

In this study, after one year seven (35%) were still using a derotation brace for sporting activities and one (5%) a knee guard. Most of the subjects were still wearing their brace during sport as it gave them confidence/psychological support and they felt better when they wore it. This is especially true in twisting sports e.g. squash. The subject that wore a knee guard wore it to "keep his knee warm".

The reasons for wearing a brace in this study reflect Tibone & Antich's (1988) reasons where most subjects wore braces for psychological support and one felt it truly helped decrease instability.

5.3 Restoration of stability

Restoration of stability (anterior-posterior and anterolateral) is the primary aim of surgery. This may not always be achieved e.g. poor surgical technique. Stability had definitely improved post-reconstruction on all tests : Lachman, anterior drawer, KT1000 and pivot shift.

5.3.1 Is there 3mm or less side-to-side difference on Lachman testing and the anterior drawer test?

The Lachman test has a reported sensitivity of 81% (Katz & Fingeroth, 1986) to 98% (Johnson et al, 1992) and is thus the most reliable test for ACL injury (Johnson & Warner, 1993). Marshall, et al, (1982) reported a 90% correlation of complete rupture of the ACL with a positive anterior drawer sign. Four of the 98 with negative drawers were seen to have a lesion at surgery and developed an anterior drawer sign at late follow-up.

A positive anterior drawer sign with an apparently intact ACL may be explained in a number of ways :

a) the antero-medial band is damaged only and is still within the synovial covering of the ACL. The posterolateral part would be present at surgery and the ACL considered normal (Firer, 1982);

b) a more likely explanation is that the ACL undergoes plastic deformation of up to 40% of its resting length (Noyes & Grood, 1976). This would give a positive anterior drawer sign but inspection would reveal an intact but (unrecognised) stretched and incompetent ligament (Firer, 1982);

c) if the PCL is damaged the tibia would drop posteriorly (due to gravity) at rest (Girgis et al, 1975). When the anterior drawer is performed the tibia will translate anteriorly from its abnormally situated posterior position, stopping in its normal position 0 - 5mm anterior from neutral. This is a false positive anterior drawer sign and a normal, intact ligament would be found at surgery (Firer, 1982).

Negative anterior drawer signs in the presence of a surgically confirmed ACL rupture can be explained as follows :-

1) although the ACL is torn, the secondary restraints (Butler et al, 1980) may be strong enough to prevent clinically detectable anterior displacement with the small loads applied during the test. Hamstring spasm and haemarthrosis may also negate a drawer sign in the acutely injured knee (Torg et al, 1976);
2) if the medial meniscus remains absolutely intact after injury, the posterior horn may prevent anterior gliding of the tibial surface under the medial femoral condyle by acting as a wedge (Torg et al, 1976). These authors also believe that a significant drawer sign occurs only peripheral separation of the posterior horn of the medial meniscus or disruption of the medial capsular and/or posterior oblique ligaments.

Gersoff & Clancy, (1988) state that the anterior drawer test is unreliable owing to the significantly high load that must be applied to produce an anterior drawer sign in those with intact secondary restraints,

The Lachman test is said to be more reliable due to :

1) the position of comfort of the acutely injured knee being one of slight flexion;
2) the force of the hamstring spasm being negated by testing near terminal extension. The force being applied to translate the tibia anteriorly is at right angles to the hamstrings and therefore only has to overcome friction and the weight of the leg (Firer, 1982);
3) the area of contact between the tibial plateau and attached medial meniscus and the slightly convex weight bearing surface of the femur in extension. The relatively flat configuration of this surface does not obstruct forward motion of the tibia in extension as obstruction of forward motion of the tibia may occur when the joint is flexed 90° (Firer, 1982).

Torg et al, (1976) compared the Lachman and anterior drawer tests in 93 patients (where a lesion was proved by arthrotomy). The anterior drawer test was positive in 40%, equal in 15% and negative in 45%. On Lachman testing, 94% were positive, 5% negative (of which all had bucket handle tears of the medial meniscus).

Katz & Fingeroth, (1986) compared results of Lachman testing, the anterior drawer test and the pivot shift test in acute and chronic injuries in anaesthetised patients. Sensitivity was defined as the number of ACL tears diagnosed by each specific test in question divided by the number of true ACL tears. Specificity signifies knees without ACL tears divided by the number of true negative ACL injuries confirmed by arthroscopy. The anterior drawer test was the least sensitive for acute and chronic injuries. Overall, the Lachman test was 81,8% sensitive and 96,8% specific, the anterior drawer sign was 40,9% sensitive and 95,2% specific while the pivot shift was 81,8% sensitive and 98,4% specific.

Side - to - side differences on Lachman and Anterior drawer testing

Table 5.2

Operated Knee			Side-to-side Difference		
Movement (mm)	Lachman (Number)	Anterior Drawer (Number)	Movement	Lachman (Number)	Anterior Drawer (Number)
1 - 2	2	1	0mm	0	6
2 - 3	3	1	1mm	4	2
3 - 4	9	4	2mm	7	5
4 - 5	4	1	3mm	6	2
5 - 6	0	6	4mm	0	1
6 - 7	0	3	5mm	0	0
7 - 8	1	3	6mm	1	0
8 - 9	0	0	7mm	0	1
9 - 10	0	0			
10 - 11	1	0	-1mm	1	1
11 - 12	0	1	-2mm		2

The reason for more patients having greater movement on anterior drawer testing (at 90°) is that the ACL is less stable at 90°. The ACL is tighter towards extension and would thus be more stable on Lachman testing at 20° - 30°.

The side-to-side differences are more comparable than actual measurements on each leg. Nineteen subjects (95%) had less than or equal to 3mm on Lachman testing while 18 (90%) had less or equal to 3mm on anterior drawer testing. One (5%) had greater than 3mm on Lachman and two (10%) on anterior drawer testing. Three subjects (15%) were tighter on the operated knee on both Lachman and anterior drawer testing.

Nineteen subjects (95%) had a firm end point on testing, indicating an intact ACL. One subject (5%) had a semi-solid end point - this correlated to a side-to-side difference of 6mm on Lachman testing and 7mm on the anterior drawer test. This indicates that the graft had stretched out or partially torn.

The student t-test indicated significant differences between the operated and unaffected knees on Lachman testing ($t = 2,76$; $p = 0,05$) and anterior drawer testing ($t = 2,72$; $p = 0,05$).

5.3.2 Is there 3mm or less side-to-side difference on testing of KT1000 at 20lbs and manual maximum testing?

Instruments have been designed to measure laxity to evaluate results as objectively as possible (Forster et al, 1989).

Daniel et al, (1985) measured laxity in 338 normal subjects and 89 with a unilateral ACL injury while Sherman et al, (1991) measured 48 normal knees and 19 injured knees. The absolute values of laxity found in a single normal knee varied widely but the difference in laxity between the knees of the same subjects varied little - this was not greater than 2mm in 92% - 95% of normal subjects. There was a wide variation in laxity between the normal and injured knees. The average laxity of the injured knee was much greater and the difference in laxity between injured and uninjured knees in the same patients was greater

than the side-to-side difference in normal subjects (greater than 2mm in 95% - 96%).

Daniel et al, (1985) suggested a side-to-side difference greater than 2mm to indicate a definite tear of the ACL (at 89N). In Forster, Warren-Smith,Tew's (1989) trial, 28% (9 of 32) of normal subjects had greater than a 2mm side-to-side difference while 31% of the injured knees had less than 2mm. The common finding of greater laxity in the "normal" knee of injured patients compared to those of uninjured subjects does suggest some physiological significance - perhaps the injured knees were already relatively lax before the injury and more susceptible to further damage. The inter- and intra- surgeon variation may arise for two reasons :

1) achieving the same degree of relaxation in the subject; and
2) trying to hold a flat pad on a rounded patella at a constant pressure during the measurement (this could be prevented by a change in design).

They concluded : "whatever the subjective causes of variation, in patients or examiner, the KT1000 arthrometer was, in their hands, not capable of overcoming them and providing a reliable, reproducible, objective measurement of laxity of the ACL. The findings in all studies that there is a greater than average laxity in the uninjured knee against which the injured knee is to be judged, together with the variability of measurements made in the ordinary knee clinic, must reduce the confidence surgeons should place in a KT1000 arthrometer as an impartial arbiter of the relative improvements achieved by different techniques for ACL reconstruction". A similar impression was created in this study.

Their conclusion may explain the discrepancy in results obtained with the KT1000 arthrometer compared to results on Lachman and anterior drawer testing in this study.

Wroble et al, (1990) conducted a study to determine the magnitude of reliability on KT1000 testing variability in six normal knees. They concluded that the standard KT1000 evaluation should report paired differences rather than individual knee measurements and that initial evaluation should be supplemented by follow-up examination for verifying translation values.

Various authors have used differing values as their failure criteria for side-to-side difference. Values have ranged from 2mm to 5mm. Howe et al, (1991) used 4mm, Yasuda et al, (1992) 2,5mm and Aglietti et al, (1992) greater than 7,5mm, but most authors seemed to use 3mm as indicative of a significant side-to-side difference on KT1000 testing (Glasgow et al, (1993); Good et al, (1994); Bach et al, (1995)). In this study 3mm was used (as accepted by the International Knee Society).

In this study, 13 subjects (65%) had a 3mm or less side-to-side difference at 89N (including four who were tighter on the operated side). If 4mm is used, 17 subjects (85%) fall into this category (of which four were tighter on the operated side). On maximum manual testing, 14 subjects (70%) had 3mm or less side-to-side difference (including two who were tighter on the operated knee). If 4mm is used, 17 subjects (85%) fall into the category (of which four were tighter on the operated knee). Three millimetres is the recommended side-to-side difference by the International Knee Society and was used in this study.

In Bach et al's (1995) study of 38 subjects with less than 3mm side-to-side difference on maximum manual testing, 31% were tighter on the operated knee. In their study there were no statistically significant differences between the tighter knees (<0mm) and the incidence of knee flexion contractures, patellar pain symptoms, crepitus, functional indices or Cybex extension deficits. They gave no explanation as to why the patients had tighter knees but they did mention that they should be followed up to determine whether they might be at higher risk for developing degenerative changes.

In this author's opinion, possible reasons for "tightness" could include :-

1) fibrosis around the knee joint;
2) decreased range of movement, i.e. loss of extension;
3) ligament inserted too tightly;
4) variations in surgical placement of the graft e.g. if the femoral ligament insertion is posterior;
5) technique of KT1000 testing;
6) possible previous, undetected injury (minor) to the opposite knee causing ligament

laxity or a minor injury to the opposite side (forgotten by the patient).

Statistically, the two tailed t-test indicated that there was a significant difference between the means of the operated knee and the unaffected knee on testing at 20lbs ($t=2,698$; $p=0,05$) and on maximum manual testing ($t = 2,488$; $p=0,05$).

The subject who had the greatest side-to-side differences on all four tests (6mm on Lachman, 7mm on anterior drawer and 20lbs KT1000, and 9mm on maximum manual KT1000) did have a positive pivot shift (Grade 2). Of the other five with a pivot glide i.e. mild pivot shift, three had a side-to-side difference of greater than 3mm on KT1000 testing (at 20lbs). Of those three, one was tighter on the operated side. Lachman and anterior drawer testing of those five subjects with a mild pivot shift i.e. pivot glide demonstrated only one subject to have a side-to-side difference greater than 3mm.

It may seem incongruent that a side-to-side difference of 3mm or less can give rise to a pivot shift. This may be explained by one of the following :-

i) the author's technique and assessment may be at fault due to the variability of results obtained with the KT1000 as concluded by Daniel et al, (1985);

ii) if a patient has a normally lax knee e.g. 6 - 7mm on Lachman testing with no injury (and a negative pivot shift as the knee is normal), a change of 3mm (to a Lachman of 9 - 10mm) may be enough to produce a pivot glide (Grade 1 pivot shift). (Firer, personal communication 1996).

Conversely, a stiffer knee with a normal Lachman of 1mm may tolerate an increase of 4 - 5mm to a 5 - 6mm Lachman and not have a pivot shift. (Firer, personal communication 1996).

Aglietti et al, (1992) & Buss et al, (1993) also found a positive correlation in their studies. This may be due to their larger sample number. There seemed to be no correlation between range of movement and an increased side-to-side difference in this study. The subjects with tighter operated knees did not seem to have a limited range of movement (the one subject

with a 4mm side-to-side difference had a range of movement of 3° - 130° while the one with -3,5mm had 0° - 127° movement). The other subjects with tighter knees had ranges of 0° - 120° and 3° - 132°. A tighter knee could limit extension or flexion due to incorrect placement of the ligament during surgery (Firer, personal communication 1996).

In two studies (Bach et al, 1995 and Good et al, 1994), there was no correlation between Cybex results and laxity measurements. This seemed to be true of this study. The subject with the highest side-to-side difference on all four laxity tests had a 10% quadriceps strength deficit. The subject with a 41% deficit had a 2mm side-to-side difference on Lachman and anterior drawer testing but a 4mm side-to-side difference on KT1000 testing at 20lbs and 2mm on manual maximum testing. The subject with a 36% quadriceps deficit was 1mm tighter on the operated knee on both KT1000 tests i.e. at 20lbs and manual maximum testing. Another subject who was 4mm tighter on the operated knee on both KT1000 tests was 2% stronger on his affected quadriceps.

Bach et al, (1995) & Glasgow et al, (1993) did find a significant correlation between the timing of surgery and post-operative knee laxity measurements. Glasgow et al, (1993) found the mean anterior-posterior laxity difference with maximum manual testing was 0,98mm for acute reconstructions (range= -6mm to 5mm); 2,6mm for intermediate reconstructions (range= -1mm to 6,5mm) and 3,1mm for chronic reconstructions (range= -4mm to 7mm). Bach et al, (1995) also found the acute group to have smaller side-to-side differences.

In this group, the average side-to-side difference in acute reconstructions was 1,3mm on Lachman testing and 1,2mm on anterior drawer testing. The average side-to-side difference on KT1000 testing at 20lbs in the acute reconstructions was 1,6mm and 1,7mm on maximum manual testing. The chronic reconstructions average side-to-side difference was 0,8mm on Lachman testing and 1,2mm on anterior drawer testing. KT1000 testing at 20lbs averaged 1,85mm and 1,65mm on maximum manual testing (see table 4.34, page 115). From the average values in this study, there does not seem to be a constant association between acute and chronic reconstructions.

The chronic group did have the widest range of values (-4mm to 7mm on 20lb KT1000 testing and -4mm to 9mm on maximum manual testing). The acute group ranged from -1mm to 5mm on 20lb testing and -1mm to 6mm on maximum manual testing.

There did not seem to be a significant association between function and laxity although subjects with tighter knees did experience more functional difficulties. A tighter knee would have a decreased range of movement which would limit function. The subject with the highest side-to-side difference found hopping and one legged squat easy but duck walking difficult. Running activities were not a problem for this subject but he was apprehensive on zigzagging. The subject with the tighter knee (-4mm difference on KT1000 testing) had difficulty with all functional activities as his limited range of movement would affect the function of his knee (he also fell into the chronic category). A subject with 1mm tightness of the operated knee was unable to hop, one legged squat or duck walk and found running extremely difficult (he fell into the acute group) and had a 36% quadriceps strength deficit which could be the cause of his functional disability. Another subject with a -3,5mm side-to-side difference (i.e. the operated knee was tighter) had difficulty hopping and was unable to squat or duck walk (chronic reconstruction). It seems that subjects with tighter knees had more difficulties in performing the functional activities. (See table 5.3 page 140).

Association between stability, timing of reconstruction and functional activities

Table 5.3

20 Pound KT1000 Side-to-Side Difference (mm)	Timing	1 Leg Hopping	1 Leg Squat	Duck Walk
-4,0mm	Chronic	Difficult	Difficult	Difficult
-3,5mm	Chronic	Difficult	Unable	Unable
-1,0mm	Acute	Unable	Unable	Unable
-1,0mm	Chronic	Difficult	Unable	Unable

Note: Subjects with tighter knees found the functional activities more difficult to perform.

Association between side-to-side difference greater than 3mm, timing of reconstruction and functional activities.

Table 5.4

Manual Maximum Side-to-Side Difference	Timing	Hopping	1 Leg Squat	Duck Walk
5mm	Chronic	Difficult	Easy	Easy
6mm	Acute	Moderate	Difficult	Easy
4mm	Acute	Difficult	Difficult	Easy
9mm	Chronic	Easy	Easy	Difficult

Note: Subjects with greater than 3mm side-to-side difference performed the functional activities with greater ease than those with tighter knees.

A reason for the lack of association between function and laxity may be that the forces necessary to induce positive clinical tests are often much less than forces during functional activities. A knee that appears to be stable during clinical laxity tests may or may not be stable when subjected to higher magnitude of forces commonly experienced in the patients daily work or sport (Harter et al, 1988). Static ligament tests e.g. Lachman test, clearly provide information critical for the differential diagnosis of ACL or ACL-related instabilities. However, these and other static ligament tests do not measure the functional capabilities of the knee under dynamic, weight bearing conditions and should therefore be reviewed as limited measures of dynamic stability and function in the ACL reconstructed knee.

Harner et al, (1992) reported that knee flexion less than 125° interferes with functional activities such as squatting and stair climbing. They reported that the loss of motion was significantly associated with timing of surgery relative to the initial injury (reconstructions within four weeks of initial injury had a higher incidence of loss of motion. Shelbourne & Nitz, (1990) confirmed this in their study. Bach et al (1994) found no difference in the incidence of flexion contractures in acute or chronic reconstructions but the authors did have a higher re-operation rate in their acute cases.

At follow-up of the subjects in this study, five subjects lost 0° - 4° extension of which three were chronic reconstructions and two acute. Three lost 5° - 10° extension of which two were chronic and one acute. Of the five subjects who had 125° or less flexion, four were acute reconstructions and one chronic. Of the five subjects with 126° - 130° flexion, all five were chronic reconstructions. In the present study, subjects undergoing acute reconstructions were implicated in the loss of flexion (see table 4.34 page 115).

5.3.3 Is a pivot shift present?

As discussed previously, the pivot shift tests antero-lateral instability i.e. anterolateral subluxation of the tibia and indicates knee dysfunction with varying degrees of laxity caused by deficient ACL and secondary ligamentous restraints (Losee, 1988).

Varying severity can result. The variation can be due to the force applied by the examiner, the resistance of the patient, the amount of compression applied to the lateral compartment of the knee, the laxity of the joint and the presence/absence of impingement during the subluxation and reduction that occurs during the pivot shift (Losee, 1988).

Pre-operatively, all subjects had a positive pivot shift (assessed by the surgeon prior to surgery). At follow-up, five subjects (25%) had a mild pivot shift i.e. pivot glide and one (5%) a moderate pivot shift i.e. 70% had negative pivot shifts.

The subject who had a moderate pivot shift had a 9mm side-to-side difference on KT1000 testing (maximum manual) and 7mm at 20lbs. Of the five with a mild pivot shift, two had a side-to-side difference of greater than 3mm on KT1000 testing at 20lbs and one less than 3mm. Two were tighter on the operated knee but still showed mild anterolateral instability. The pivot shift was demonstrated but the cause of the shift was not apparent.

O'Brien et al, (1991) reported 84% were negative on pivot shift testing, while 12 had a perceptible movement (rated 1+) and one a clunk or jump (2+). Together they made up 16% of his study's sample.

Buss et al, (1993) stated that 89% of their sample (57 of 64) had a negative pivot shift. Of the remaining seven, 3% had a Grade one (glide) and 8% a grade two (shift). Five knees were not tested with the pivot shift - those unreported five cases could have changed the percentage of negative shifts.

Cosgarea et al, (1995) found that 97,3% had negative pivots and only 2,7% had a trace/glide.

One reason for this study having a higher percentage of glide or moderate pivot shift was that the slightest movement, if palpable, was recorded as positive.

5.4 Functional outcome

5.4.1 Is the subject coping with the functional demands of his knee?

(Refer to stability and function (table 5.3, page 140) and association of muscle weakness and isokinetic strength testing and function (see 5.1.3.1, page 123).

Most subjects were coping with the demands placed on their operated knee during their normal ADL. Vigorous levels of activity resulted in more having anticipating problems with their knee. Fifteen subjects admitted to still being apprehensive about their operated knee at high levels of activity (although none were apprehensive during their normal day). During normal ADL, one had slight problems with walking, three had moderate to severe problems on squatting, while stairs were not a major problem for anyone. No subjects had any problems while running for a short distance in a straight line. Zigzagging and jumping place higher demands on the knee, resulting in more problems. Five had slight problems during ADL, one severe and two did not squat during normal ADL. Two subjects had slight to moderate problems on jumping while three did not jump during their normal day.

At the subjects' highest level of intensity i.e. more vigorous activity, all activities were more difficult. Compared to the 19 (95%) subjects who had no problems walking during their normal day, five (5%) would have slight to moderate problems walking at their highest intensity. Fifteen (75%) subjects had no problems squatting once or twice during their normal day, but only eight (40%) could squat repeatedly without developing any problems. Nineteen (95%) subjects had no problems walking up stairs during their normal day and 14 (70%) had no problems at higher intensities. No subjects had problems going downstairs during their normal day and 12 (60%) did not have problems at higher intensities. Nineteen (95%) could run during their normal day and ten (50%) had no problems on running at full pace. Zigzagging resulted in 12 (60%) subjects having no problems during their normal day but only five (25%) subjects had no problems at higher demands. Fifteen (75%) subjects had no problems jumping once or twice but on repetitive jumping, only seven (35%) would manage without problems. (See table 4.15, page 100).

Hopping and squatting on one leg were difficult activities for the operated knee. Twelve (60%) subjects were unable to hop or found it difficult to moderately difficult, while 13 (65%) subjects were unable to squat on one leg or found it difficult to moderately difficult. Although the number of subjects who had difficulties performing these two activities is high, these specific activities are not commonly performed during a normal working day.

All subjects could cope with the demands placed on their knee during normal day to day activities of walking, running and going up/down stairs.

Functional difficulties were associated with quadriceps weakness. Six of the seven subjects with quadriceps deficits greater than 20% performed the functional activities with difficulty. (See table 5.1, page 126).

5.3 Does physiotherapy affect the outcome of the reconstruction?

Of the two dissatisfied subjects, one subject attended physiotherapy for less than six weeks. He had not returned to his preferred sport and complained of stiffness at rest, muscle weakness and a sensation of giving way on twisting. He had a limited range of movement i.e. 10° - 125°. His side-to-side Lachman difference was 2mm. His KT1000 side-to-side difference was 4mm. He had a pivot glide and a significant 41% quadriceps strength deficit. He admitted to only following the rehabilitation programme occasionally. He also admitted to returning to certain activities before the recommended time e.g. driving within a few days post-operatively and running at approximately six weeks. This premature loading of his knee would have affected his final outcome. His 41% strength deficit would also contribute to his poor final result. This deficit would correlate with his feelings of muscle weakness and his sensation of giving way on twisting. His lack of full extension would also affect the return of his quadriceps strength, as full extension is needed to retrain quadriceps.

The other dissatisfied subject attended physiotherapy for eight weeks and felt his knee was worse post-surgery. He had not returned to his preferred sport. He complained of pain, stiffness in the morning, muscle weakness and giving way with moderate activities. His range of movement was 0° - 120°. His side-to-side Lachman difference was 2mm but on KT1000 testing, he was 1mm tighter on the operated side. He had a pivot glide and his quadriceps deficit was 36%. He followed the rehabilitation programme very closely. His significant 36% quadriceps deficit contributed to his pain, muscle weakness and giving way.

Two other subjects attended physiotherapy for less than six weeks. Both were satisfied and felt that surgery was worthwhile but neither had returned to their preferred sport. One complained of stiffness after activity, muscle weakness and a sensation of giving way with directional change. His range of movement was 0° - 127°. His side-to-side Lachman difference was -1mm while KT1000 testing also revealed the operated leg to be tighter (a side-to-side difference of - 3,5mm). His quadriceps strength deficit was 14%. He admitted to following the rehabilitation programme sometimes. The other subject's range of

movement was 0° - 140°. His side-to-side Lachman difference was 6mm while KT1000 testing showed a side-to-side difference of 7mm. A moderate pivot shift was present. His quadriceps deficit was not significant i.e. 10%. He claimed to have followed the rehabilitation programme most of the time.

The significant tightness of the operated leg in the one subject could have prevented return of full flexion. This other subject with the significant 7mm side-to-side difference had not returned to soccer as his knee felt like giving way while playing. His moderate pivot shift suggests the presence of anterolateral laxity.

As the subjects who attended physiotherapy for less than eight weeks had poorer overall results, the length of rehabilitation may be a significant factor in determining the outcome in this study.

A possible reason for more chronic subjects having less range of movement is the abnormal arthrokinematics of the tibiofemoral joint pre-reconstruction resulting in stretching of secondary restraints, meniscal injury and joint surface degeneration. These reasons may also explain why less chronic subjects returned to their preferred sport. It must be remembered that some subjects did not return to their preferred sport on the advice of their surgeon.

Of the four subjects who attended physiotherapy for less than eight weeks, three complained of stiffness, all felt their operated leg was weaker (although only three had a deficit greater than 10%) and three complained of giving way on different activities. Only one had full range of movement. Three had a pivot glide (i.e. mild pivot shift) and one a moderate pivot shift. Continuing physiotherapy for longer than eight weeks would probably have strengthened their legs and increased their range of movement further, possibly resulting in improved function.

Although the rehabilitation programme followed by the subjects varied as different physiotherapists were recommended, the subjects did follow the same basic programme

according to the surgeon's instructions. Eleven subjects (55%) went to physiotherapist A, two (10%) to physiotherapist B, two (10%) to physiotherapist C, three (12,5%) to physiotherapist D, one (5%) to physiotherapist E and one (5%) to physiotherapist F. Therefore, six therapists were involved in rehabilitating these subjects resulting in rehabilitation variables. Various therapists were recommended by their surgeon for the convenience of the subjects.

Unfortunately, documentation files on rehabilitation of these subjects was extremely poor and could not be followed up by the researcher, despite many efforts to trace files and evaluate the exact protocol being followed. Of the 11 subjects who went to the same physiotherapist, no records were available as he had sold the practice and had not handed over the records. It appears that a similar rehabilitation programme was followed by the physiotherapists as instructed by the orthopaedic surgeon.

As surgical techniques have improved, the conventional rehabilitation protocol (followed by subjects in this study) has been changed to an accelerated protocol. Shelbourne & Nitz (1990) claim improved results following the accelerated programme especially in regaining full extension. There is no other literature to substantiate their claim.

The accelerated programme would decrease the cost and time required for physiotherapy. According to Speechly, (1992), the advantages of an accelerated programme include :-

1. increased compliance - a common problem encountered with the conventional protocol is non-compliance. It was by following up the non-compliant patients that Shelbourne and Nitz, (1990) first considered the accelerated programme, since these non-compliant patients returned to normal function quicker than the compliant patients, without any knee instability. With the accelerated protocol, patients are exercising almost immediately post-operatively and are less likely to become frustrated;
2. decreased incidence of patellofemoral joint symptoms;
3. improved range of movement;
4. earlier return to normal function;

5. earlier return to sport;
6. cost with the conventional protocol, many physiotherapists encouraged their patients to attend physiotherapy three times a week for up to nine months. With the accelerated protocol, the number of physiotherapy sessions are reduced.

After reviewing the literature and assessing the outcome of patellar tendon reconstructions, the following factors may influence the outcome of the reconstruction :

1. initial injury. The more structures damaged at the time of injury may influence the outcome e.g. isolated ACL reconstruction compared to a combined ACL, MCL and meniscal repair;
2. associated damage at the time of reconstruction. As stated previously (see page 2) a chronically ACL deficient knee results in abnormal arthrokinematics, meniscal damage and deterioration of joint surfaces. This associated damage can affect the long-term outcome of the reconstruction;
3. timing of reconstruction. Most authors (Noyes et al, (1992), Shelbourne et al, (1991), Mohtadi et al, (1991) seem to agree that delaying surgery post-injury instead of an acute reconstruction can improve results;
4. surgical technique. Factors like isometry, graft placement and graft selection will affect the outcome;
5. effective supervised rehabilitation programme for an adequate period of time. The post-operative rehabilitation programme is vital to increase range of movement, decrease pain and strengthen the affected leg so the patient can return to his preferred sport. Patients who undergo physiotherapy for a short period of time may not strengthen adequately which may result in residual symptoms e.g. pain or giving way and not being able to return to their preferred sport. They may experience difficulties performing functional activities;
6. significant strength deficits of quadriceps and hamstrings (compared to the opposite leg) especially a quadriceps deficit. Persistent quadriceps deficits may result in residual symptoms, giving way and functional difficulties.
7. successful restoration of stability (antero-posterior and antero-lateral). The aim of surgery is to restore stability, but this may not always be achieved.

Stressing the ligament prematurely may also result in graft stretch-out.

5.6 Limitations of this study

Limitations exist in this study :

1. lack of pre-operative data - if detailed pre-operative data was available, comparisons could have been made pre- and post-operatively.
2. the small sample size - over 200 names were obtained from the surgeon. Many subjects were lost to follow-up because patients had moved leaving no forwarding address or contact numbers and were untraceable. Others lived out of the country or too far away to be assessed. This would have increased the sample size. The outcome, satisfaction and results of those subjects lost to follow-up would have affected the results obtained in this study.

   As Gillquist (1993) states: "If you absolutely want to publish, there are ways to reach the magic success figure of >75%. One way is to have a low follow-up rate. There may not be a way to improve the follow-up rate, but you can use the low rate to your advantage."

   The many exclusion factors also contributed to the small sample size. Another reason for the small sample was attempting to get as homogeneous a sample as possible for research purposes. This was done but resulted in a small sample size. Patients having previous surgery on the injured knee were excluded as were patients with other associated injuries as they could affect the outcome of the reconstruction. Many authors include all patients (irrelevant of the status of their knee injury) in their studies which may "average out" poor results. The final outcome of the reconstruction and patient satisfaction may be affected by including this wide range of patients e.g if a patient had pain at follow-up, was it due to the reconstruction, a previous surgical procedure or an unrepaired associated injury? Although the sample is small, trends in results can be seen, but no definite conclusions can be made.

3. variability of the rehabilitation. The same basic protocol of rehabilitation was used by the different physiotherapists as instructed by the orthopaedic surgeon. The orthopaedic surgeon and physiotherapists work closely together and a basic rehabilitation programme has been worked out by the surgeon and the physiotherapists that he refers to. Despite this, tracing of records was a difficult, often unsuccessful task. Referral to different therapists is a difficult factor to overcome in research as the patient has the right to choose a therapist and will usually choose one in his area;

4. choice of functional tests used. There is huge variability in the functional tests used and there seems to be no standardised test for evaluation of function. The interpretation of these tests also vary greatly. In retrospect, the one-legged hop for distance seems to be a more commonly used test by some authors and it could have been utilised in this study. It must be remembered that different authors have many different methods of assessing the outcome of their results and can choose their own method as no standard evaluation is recommended.

5.7 Suggestions for future research

1. Assess results in females of the same age group and compare the results. This will help with prognoses for future subjects undergoing patellar reconstructions (male or female).
2. Assess results in males of a wider age group to assess if age affects outcome.
3. Compare results at 12 months post-reconstruction to five to ten year follow-up to see if there is any change of results with time.
4. Assess results of semitendinosus reconstructions in the same age group to assess which reconstruction results in a better outcome.
5. Compare results in the average athlete to elite athletes to assess if elite athletes have a better prognosis than the average athlete.
6. Compare results of allografts and autografts tc assess which results in the best outcome for the patient.

6.0 CONCLUSION

This retrospective study concludes that the intra-articular patellar tendon reconstruction can be recommended for the active athlete who ruptures his ACL. With good surgical technique and a supervised rehabilitation programme, 18 (90%) of subjects were subjectively satisfied with the outcome of the surgery, 19 (95%) returned to some form of sporting activity, stability was restored and function improved. Eight (40%) were able to return to their pre-injury level of sport. This result will vary according to the level of participation and the sport the subjects are involved in. Some subjects chose to modify their sports due to fear of re-injury while others involved in contact sports were advised to change to a non-contact sport by their surgeon.

Thus, in this study, function of the knee was successfully restored after an intra-articular bone-patellar tendon-bone ACL reconstruction.

Although 14 (70%) had pain or discomfort, it was intermittent and usually provoked by kneeling or jumping. Stability was improved in all subjects although some still had a mild pivot shift or greater than 3mm side-to-side difference post-reconstruction. In this study, post-operative giving way was due to residual muscle weakness rather than a mechanical cause. Persistent quadriceps strength deficits greater than 20% were still present in seven (35%) subjects at follow-up.

SUBJECT INFORMATION AND CONSENT FORM

Twelve to forty eight months ago you had surgery for a torn anterior cruciate ligament. After surgery you received physiotherapy to help rehabilitate your leg and knee. I am asking you to participate in a research study which will evaluate the outcome of your operation.

Your surgeon has agreed to you, his patient, being assessed in this study. If you agree to participate, I will need permission to have access to your medical file from your orthopaedic surgeon, to gain further information about your injury and operation. Your confidentiality will be maintained at all times.

Participation is voluntary and you are free to refuse to participate or withdraw your consent or to discontinue participation at any time. Refusal or discontinuation will not affect further treatments or examinations in any way.

After reading and signing this consent form, a questionnaire will be given to you to complete. If you have any queries at any time, please ask the researcher for help. Once the questionnaire has been completed, your knee will be assessed and examined. The examination will consist of further questioning, a functional assessment of your knee (requiring walking, squatting, running and jumping, if possible) and ligamentous tests which test the stability of your knee.

The laxity of your ligament will be tested using the KT1000 arthrometer on both the operated and unoperated leg. Your muscle strength will be evaluated on both the operated and unoperated leg using a Cybex II isokinetic dynamometer. This will involve performing the test three times for both the quadriceps (which straighten the knee) and hamstrings (which bend the knee). This will conclude the session. No more visits will be required after this.

Participation in this study will help assess the stability and function of your knee. It will also convey if you are satisfied with the outcome of your operation and rehabilitation and inform us whether you have returned to your pre-operative level of activity.

The success of this study depends on information obtained from the questionnaire and therefore should be as accurate as possible. If in doubt during the examination of completion of the questionnaire, the researcher will gladly provide assistance. Participation is voluntary. A signed copy of this consent form will be made available to you at your request.

I have fully explained the procedure and explained the rationale. I have asked whether or not any questions have arisen regarding the procedure and answered questions to the best of my ability.

DATE:_____ RESEARCHER: _____

I have been fully informed as to the procedure to be followed. In signing this consent form, I agree to fill in the questionnaire and have an assessment on my knee, a test of muscle strength using the Cybex II isokinetic dynamometer and a test of ligament laxity on the KT1000 arthrometer. I understand that I am free to refuse to participate or withdraw my consent and discontinue my participation in this study at any time. I understand also, that if I have any queries at any time, they will be answered by the researcher.

DATE: _____ PATIENT: _____

APPENDIX B

QUESTIONNAIRE

DATE: _____

NAME: _____ AGE: _____

ADDRESS: _____ DATE OF INITIAL INJURY: _____

OCCUPATION: _____ DATE OF OPERATION: _____

TELEPHONE: _____ DATE OF BIRTH: _____

PLEASE TICK THE CORRECT ANSWER

If you are unsure of how to answer any questions, please ask the researcher for assistance.

1. GENERAL

a) Pain

Do you have any pain in your operated knee? YES NO

If NO, move onto (b).

If YES, is it:

1) in front of your knee _____
2) above your knee-cap _____
3) behind your knee-cap _____
4) below your knee-cap _____
5) other _____

Where? _____

When do you get your pain?

1) all the time _____
2) in the morning on awakening _____
3) in the evening _____
4) during strenuous activity e.g. pivoting, jumping, deceleration _____
5) during moderate activity e.g. jogging, tennis, hiking _____
6) during minimal activity e.g. walking, standing _____
7) at rest _____
8) any other _____

What movements or activities make your pain worse?

1)	stairs	_____
2)	[illegible]ing	_____
3)	kneeling	_____
4)	standing	_____
5)	running or jumping	_____
6)	other	
	Explain:	_____

How long does it take for your pain to return to its previous level?

1)	momentary	_____
2)	few minutes (1-30 min.)	_____
3)	1/2 hr. to 1 hour	_____
4)	longer than 1 hour	_____
5)	longer than a few hours	_____

b) Stiffness

Does your knee feel stiff? YES NO

If YES, is it:

1)	worse in the morning	_____
2)	worse in the evening	_____
3)	worse after activity	_____
4)	worse after rest	_____

c) Muscle Strength

Do you feel a difference in the strength of your legs? YES NO

If YES, which leg feels weaker? Operated Unoperated

d) Giving way and Locking

Does your knee "give way" at all? YES NO

If YES:

1)	occasionally with twisting or jumping (± 1-2 x year)	_____
2)	gives way with moderate activity e.g. jogging, hiking, dancing (± 6 x yr.)	_____
3)	gives way with moderate activity but occasionally with walking (± 1 x month)	_____
4)	gives way frequently with walking or directional change (several times/month)	_____
5)	disabling (affects walking)	_____

Does your knee "lock" at all? YES NO

If YES: 1) How often? _____

2) When? _____

2. **SPORTS/HOBBIES**

What sport do you play? _____

_____

Level of participation before your injury:

1) recreational/social _____
2) league _____
3) provincial _____
4) national _____

Have you returned to your preferred sport since your operation? YES NO

How long after your operation did you return? _____

Level of participation now:

1) recreational/social _____
2) league _____
3) provincial _____
4) national _____

How many times do you play per week?

1) 1 _____
2) 2-3 _____
3) 3-4 _____
4) more than 4 _____

Do you wear a brace now for sporting activities? YES NO

Did you wear one previously? YES NO

For how long? _____

3. OPERATION AND REHABILITATION

Surgeon: _____ Physiotherapist: _____

Did you continue with your physiotherapy after your discharge from hospital? YES NO

Did you have any complications after your operation? YES NO

If YES, what? _____

_____

Did you follow the exercise programme given to you by your physiotherapist?

1) yes, very closely _____
2) yes, most of the time _____
3) sometimes _____
4) not at all _____

How long did you follow the programme or attend physiotherapy?

1) 1 year or more _____
2) 6 months - 1 year _____
3) 6 weeks - 6 months _____
4) less than 6 weeks _____

Why did you stop the programme?

1) participated for longer than 1 year or the physiotherapist said I could stop _____
2) exercise was painful, so I stopped _____
3) felt the exercises were no longer necessary _____
4) low motivation _____
5) not enough time _____
6) couldn't afford rehabilitation any longer _____

Outcome of operation and rehabilitation:

1) very satisfied, knee returned to normal _____
2) satisfied, improved knee but not normal _____
3) unsatisfied, improved knee but not enough _____
4) unsatisfied, no change in knee _____
5) unsatisfied, worsened _____

Do you feel that undergoing surgery was worthwhile? YES NO

4. RE-INJURY

Have you re-injured your knee since returning to sport? YES NO

If YES:
1) did you have pain and/or swelling for less than 2 weeks with a slight limitation of activity _____
2) did the pain and/or swelling last longer than 2 weeks or require treatment _____

How many time have you re-injured your knee?
1) 1-3 _____
2) 4-8 _____
3) 8-10 _____
4) 11 + _____
5) unknown

Have you injured another part of your body since returning to sport? YES NO

Where and how? _____

_____

_____

Do you think it was related to your knee? YES NO

Explain: _____

_____

5. FUNCTIONAL ASSESSMENT

The following questions will be answered together with the researcher. Please CIRCLE the correct answer.

a) Activities

At what level do you perform each of the following activities?

Intensity level: 1 = slight
2 = moderate
3 = vigorous
4 = highest level

1)	Disabled	0
2)	Work, activities of daily living	1 2 3 4
3)	Work, manual labour, light agility (jogging, running)	1 2 3 4
4)	Work, manual labour, heavy agility (skiing, tennis)	1 2 3 4
5)	Jumping, pivotting, hard siz-zagging (football, rugby)	1 2 3 4

b) Working capacity

At what level can you work at now compared to before your injury?
0% <25% <50% <75% ≤100%

c) Patient functional assessment

How do you rate the function of your knee?
Mark the line between 0 to 10 - 0 = knee at it's worst
10 = knee at it's best

0 _____ 10 Before injury

0 _____ 10 Before operation

0 _____ 10 Now

d) Intensity level

At what level of activity do you get the following symptoms:

1 = Activities of daily living (ADL)
2 = At your highest level of activity

e.g. if you get no swelling while mowing the lawn (ADL, circle 1 in the NONE row, if you get severe swelling while playing soccer (your highest level of activity), then circle 2 in the SEVERE row. The same procedure should be followed for each symptom.

NOTE: Your response shoud result in each symptom/column having both a "1" and a "2" encircled.

	Swelling	Pain	Apprehension	Giving Way	Locking
None	1 2	1 2	1 2	1 2	1 2
Slight	1 2	1 2	1 2	1 2	1 2
Moderate	1 2	1 2	1 2	1 2	1 2
Severe	1 2	1 2	1 2	1 2	1 2

e) Functional activities

During ADL (1) and at your highest level of activity (2), are any functional disabilities experienced during the following activities:

NOTE: Your response should result in each activity/column having both a "1" and a "2" encircled. If you do not perform any of these activities, please state the activity and the reasons why you do not perform them.

	Walking	Squatting	Up Stairs	Down Stairs
None	1 2	1 2	1 2	1 2
Slight	1 2	1 2	1 2	1 2
Moderate	1 2	1 2	1 2	1 2
Severe	1 2	1 2	1 2	1 2

	Running	Zig-zagging	Jumping
None	1 2	1 2	1 2
Slight	1 2	1 2	1 2
Moderate	1 2	1 2	1 2
Severe	1 2	1 2	1 2

Zig-zagging = a directional change during sporting activities.

PHYSICAL EXAMINATION

1. Functional tests

a) Function

	FREE	DIFFICULT	UNABLE	TIME/DIST.
One leg hop to side	____	_____	_____	_____
One leg squat (holding on)	____	_____	_____	_____
Duck squat	____	_____	_____	_____
Figure of 8 running	____	_____	_____	_____
Running there and back	____	_____	_____	_____
Slalom/zig zag running	____	_____	_____	_____

2. Active Range of movement (measure with goniometer)

_____

Limited by: - Pain
- Stiffness

3. Sagittal translation (measure with ruler in mm)

		Neutral	1-2	3-4	5-6	7-8	9-10	11-12
a)	25 degrees	_____	___	___	___	___	____	_____
b)	90 degrees	_____	___	___	___	___	____	_____

4. Valgus / Varus (mm)

		8-7	6-5	4-3	2-1	Neutral
a)	Valgus 0 degrees	___	___	___	___	_____
b)	Valgus 25 degrees	___	___	___	___	_____
c)	Varus 0 degrees	___	___	___	___	_____
d)	Varus 25 degrees	___	___	___	___	_____

5. End point quality

		FIRM	SEMI-SOFT	SOLID
a)	Lachman at 25 degrees	____	_____	_____
b)	Anterior drawer 90 degrees	____	_____	_____

6. Synovial thickening and effusion

None _____
Mild _____
Moderate _____
Severe _____

7. Quadriceps atrophy (measure with tape measure in cm)

	AFFECTED KNEE	UNAFFECTED KNEE
10cm above patella	_____	_____
5cm above patella	_____	_____
Mid patella	_____	_____

8. Patellofemoral joint (compared to unaffected knee)

		INCREASED	NORMAL	DECREASED
a)	Motion- transverse			
	longitudinal			

		YES	NO	MILD	MODERATE	SEVERE
b)	Crepitus					
c)	Pain/tender- ness					
d)	Lateral instability					
e)	Medial instability					

9. Compartment findings

		NONE	MILD	MODERATE	SEVERE
a)	Medial compartment:				
	Crepitus				
	Tenderness				
	Meniscus				
b)	Lateral compartment:				
	Crepitus				
	Tenderness				
	Meniscus				

10. Pivot shift (ACL)

0		NONE
1		MILD
2		MODERATE
3		SEVERE

11. Laxity of ACL (measure on KT-1000 arthrometer in mm)

11a) 20lb test

Operated knee
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Unoperated knee
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Difference = _____

11b) Maximum manual test

Operated knee
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Unoperated knee
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Difference = _____

12. Muscle strength (measure on Cybex II isokinetic dynamometer)

Affected knee =	RIGHT 60 °/sec.	LEFT 180 °/sec.	240 °/sec
Quadriceps (right)	_____	_____	_____
Quadriceps (left)	_____	_____	_____
Hamstrings (right)	_____	_____	_____
Hamstrings (left)	_____	_____	_____

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