CORRELATION OF MAGNETIC RESONANCE IMAGING AND ARTHROSCOPIC FINDINGS IN PATIENTS WITH SOFT TISSUE KNEE INJURIES

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Declaration

I, Thando Ncube declare that this research report is my own unaided work. It is being submitted for the degree of Master of Medicine in the branch of Orthopaedic Surgery at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

Signed: ....

Date: 14/02/18

Dedication

To my wife and children, thank you for your support throughout the time I spent working on this research.

To my parents, I thank you for the sacrifices you made for me to get to this point.

Presentations arising from this research project

Work from this research was accepted for oral or poster presentations at the following conferences

1. International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) Biennial Congress, June 2017, Shanghai, Histopathological audit of arthroscopic synovial biopsies done for persistent knee effusions, Oral presentation

2. South African Orthopaedic Association (SAOA) 63rd Annual Congress, September 2017, Port Elizabeth, Correlation of knee MRI and arthroscopic findings and the effect of time on diagnostic reliability, Oral presentation

3. 1st Cape Town Trauma Conference (CTTC), November 2017, Cape Town, Correlation of knee MRI and arthroscopic findings and the effect of time on diagnostic reliability, Oral presentation

4. 1st Cape Town Trauma Conference (CTTC), November 2017, Cape Town, The burden of knee ligamentous injuries at Chris Hani Baragwanath Academic Hospital, Oral presentation

5. International Society of Orthopaedic Surgery and Traumatology (SICOT) 38th Orthopaedic World Congress, December 2017, Cape Town, Histopathological audit of arthroscopic synovial biopsies done for persistent knee effusions, Oral presentation

6. International Society of Orthopaedic Surgery and Traumatology (SICOT) 38th Orthopaedic World Congress, December 2017, Cape Town, Correlation of knee MRI and arthroscopic findings and the effect of time on diagnostic reliability, E-poster

Abstract

The knee is indispensable in everyday life and injuries to it can be debilitating with significant loss of earnings incurred. Clinical diagnosis may not always be made with certainty and Magnetic Resonance Imaging (MRI) helps further elucidate intra-articular injuries. MRI reporting has its shortcomings and may provide spurious results according to the interpretor's level of experience. This study aims to test the diagnostic reliability of MRI done in a teaching hospital for the evaluation of anterior cruciate ligament and meniscal injuries using arthroscopy as the baseline for comparison. Due to the long waiting times to have surgery we also determined if there was a change in the reliability of an MRI result as time elapsed. A retrospective review of records of patients who had knee arthroscopies at Chris Hani Baragwanath Academic Hospital (Johannesburg, South Africa) from May 2009 to May 2015 was done. Adults (16 − 60 years) with one major episode of trauma to the knee and had MRI done prior to surgery at the above institution were included. Arthroscopy was performed by 2 senior surgeons or by residents under their direct supervision. Arthroscopic findings of anterior cruciate ligament (ACL) and medial (MM) or lateral meniscal (LM) injuries were compared to MRI findings. Data was analysed by STATA version 13.1 to determine injury demographics, sensitivity, specificity and diagnostic accuracy of MRI. The effect of time interval from MRI to surgery on the diagnostic accuracy was determined. A total of 72 patients (74 knees) qualified for review. The median age was 35 years (IQR 26 − 43) with a significant difference between males and females (28 *vs* 41 years, $p = 0.0019$). Leading causes of injury were traffic accidents (32.4%), falls (27.0%) and sports injuries (17.6%). Median interval from MRI to surgery was 71.5 days (IQR 29 − 143). The sensitivity of MRI for ACL, MM and LM injuries was (63.6%, 58.8% and 52.6%), specificity (92.7%, 86.0% and 80.0%) and diagnostic accuracy (79.7%, 79.7% and 73.0%) respectively. The patients were divided into subgroups of early (< 6 weeks), intermediate (6 − 16 weeks) and late intervention (> 16 weeks) post-MRI. There were marked differences in the diagnostic accuracy in the three groups for the ACL (70.8% *vs* 92.6% *vs* 73.9%) and LM (62.5% *vs* 81.5% *vs* 73.9%). This was unremarkable for the MM (75.0% *vs* 81.5% *vs* 82.6%). MRI findings correlate well with arthroscopic findings making it a reliable preoperative screening tool for ACL and meniscal injuries. However its diagnostic accuracy appears to change with time. It is apparent that the diagnostic accuracy is higher between 6 − 16 weeks post MRI. A bigger cohort would help determine an ideal waiting time interval without significant depreciation in diagnostic accuracy.

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The Beit Trust (UK) for sponsoring my training and helping me achieve my lifelong ambition.

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Abbreviations

ACL: Anterior cruciate ligament

CHBAH: Chris Hani Baragwanath Academic Hospital

CT: Candice Truda

FN: False negative

FP: False positive

FS: Fat suppressed MRI sequence

IQR: Interquartile range

LM: Lateral meniscus

MCC: Matthew's correlation coefficient

MM: Medial meniscus

MRI: Magnetic Resonance Imaging

NPV: Negative predictive value

ONPK: Osteonecrosis of post-operative knee

PD: Proton density MRI sequence

PPV: Positive predictive value

RRR: Relative risk ratio

SKM: Sebastian Keith Magobotha

STARD: Standards for Reporting Diagnostic Accuracy

T1: short time to echo and short time to relaxation MRI sequence

T2: short time to relaxation and long time to echo MRI sequence

TN: True negative

TP: True positive

vs: versus

CHAPTER ONE: INTRODUCTION

The knee is indispensable in everyday life because of its integral role in locomotion. Injuries to it can be debilitating and lead to significant loss of earnings, pain and suffering. The scourge of trauma from South Africa's high rate of motor vehicle accidents cannot be over-emphasised. The contribution of sport related injuries cannot be overlooked, with increasing incidence of injuries in children and adolescents engaging in sport at a younger age.

Diagnosis of soft tissue knee injuries is based on history, clinical examination and adjuncts like ultrasound and magnetic resonance imaging. The role of MRI in the diagnosis of intraarticular soft tissue knee injuries is well established in the literature. In a metanalysis of 29 studies, Oel et al. (2003)[1] reported pooled weighted sensitivity and specificity of ACL (94.4% and 88.4%), MM (93.3% and 88.4%) and LM (79.3% and 95.7%). MRI improves the diagnostic confidence even when clinical examination is performed by a highly specialised clinician[2]. Furthermore, it may obviate the need for surgery or lead to surgery in a case planned for conservative management[2]. Arthroscopy is the de facto standard of care in the diagnosis and treatment of intraarticular knee pathology. However, like other surgical procedures it is subject to complications ranging from tourniquet complications, compartment syndrome, septic arthritis, deep venous thrombosis, and osteonecrosis of postoperative knee (ONPK). Therefore, an accurate preoperative assessment is necessary before embarking on surgery. Figure 1.1 on page 3 shows an arthroscopy being performed.

The value of preoperative MRI has been scrutinised in the literature. Stanitski (1998)[3] argues that clinical assessment is sufficient to make a diagnosis and one can proceed to surgery without performing MRI. Bouju et al. (2011)[4] report that "MRI serves as a diagnostic indicator and should not be considered as the absolute truth, the experience of the Orthopaedic surgeon is primordial". In his thesis Crane [5] reports that "clinical evaluation alone is sufficient to diagnose meniscal pathology accurately and consistently, regardless the experience of the examiner. Specialised tertiary investigations (e.g. MRI) provide no diagnostic or financial benefit for the patient".

Nevertheless, it suffices to mention that the above assertions[3, 4] are premised on studies of paediatric patients, who essentially are a special group with particular characteristics. Furthermore, MRI is a useful study with no risks of radiation to the patient. In addition, it is a useful adjunct in this era of increasing litigation in medical practice.

Few studies have tested the diagnostic validity of MRI in the setting of a large teaching hospital with interpretation by a vast number of radiologists with differing levels of experience. In addition, a number of studies have been conducted by musculoskeletal radiologists and questions may be raised as to whether results can be comparable to those in a teaching hospital. This knowledge gap on how MRI and arthroscopy results in a teaching hospital correlate needs to be explored.

In the literature review, we found that several studies include young and elderly patients. It is well known that menisci and cruciate ligaments degenerate with age and the changes may appear on MRI but not be apparent on arthroscopy[6]. Furthermore, the menisci are hypervascular at a young age and the appearance on MRI may mimic a tear. This negatively impacts on the perceived diagnostic accuracy of MRI by increasing the number of false positives. Therefore, upper and lower age limits should be specified for the study.

Some papers delved into the effect of time interval from performing MRI to surgery on the diagnostic accuracy and showed that there was no association[7]. We postulate that our patients wait much longer to have surgery because of resource constraints and other reasons therefore making it pertinent to determine if that has an effect on the validity of MRI as a diagnostic modality. Determination of the incidence of intraarticular soft tissue injuries is also warranted. Such a study will be the first of its kind in our clinical setting and will contribute to the body of knowledge on the topic in South Africa.

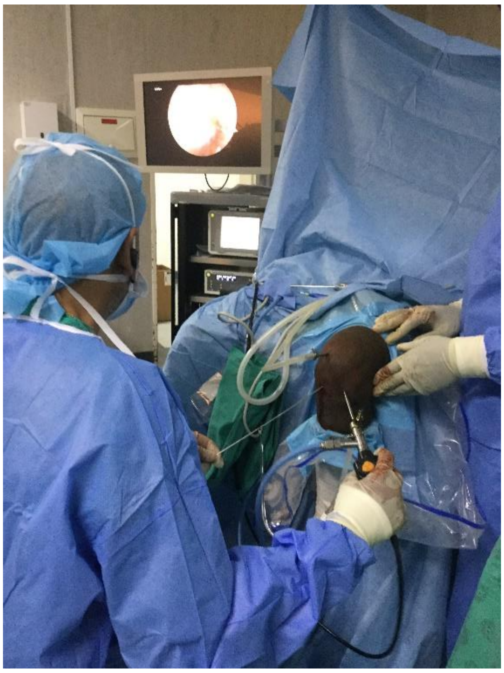

Figure 1.1 Clinical image of an arthroscopy procedure of the left knee. The patient is supine and the knee is flexed. Note the lateral viewing portal, medial instrumentation portal and superomedial water outflow portal.

1.1 THE ANTERIOR CRUCIATE LIGAMENT

The anterior cruciate ligament (ACL) is a tibiofemoral articulation ligament which offers anteroposterior and rotatory stability. It consists of two bundles namely the anteromedial (AM) and posterolateral (PL) that function synergistically. It is extrasynovial and intraarticular with an hourglass shape. Its femoral insertion (footprint) is at the lateral condyle bordered posteriorly by the condylar cartilage and anteriorly by the cruciate or lateral intercondylar ridge. The two bundles are separated by the bundle or bifurcation ridge. The footprint has an area of 18 x 10mm and is vertically oriented at a 26° angle.

The tibial insertion is 120% broader than the femoral insertion. It lies on the prespinal surface with the anterior edge 14mm from the anterior part of the tibial plateau. The AM and PL bundles are named after their tibial insertions with the AM occupying 52% of the total insertion area[8,9]. Figures 1.2 through 1.6 overleaf demonstrate various arthroscopic appearances of the ACL from normal to abnormal including grafts.

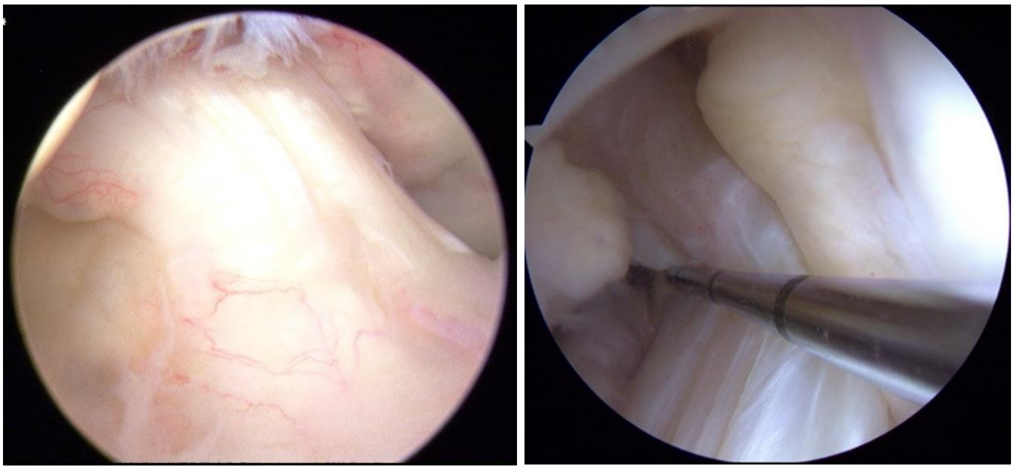

Figure 1.2 Arthroscopic appearance of intact anterior cruciate ligament

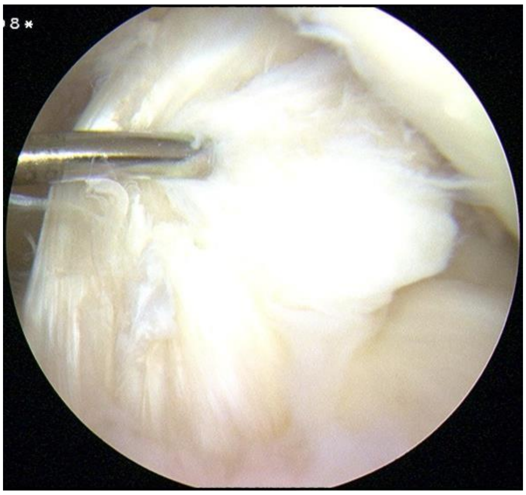

Figure 1.3 Degenerate anterior cruciate ligament with absent synovial layer

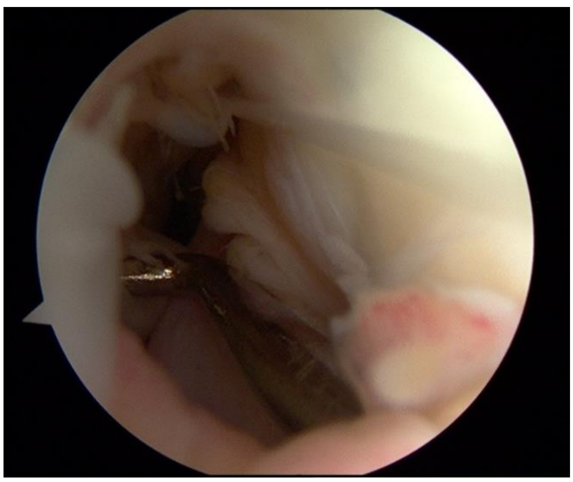

Figure 1.4 Absent ACL or empty notch sign

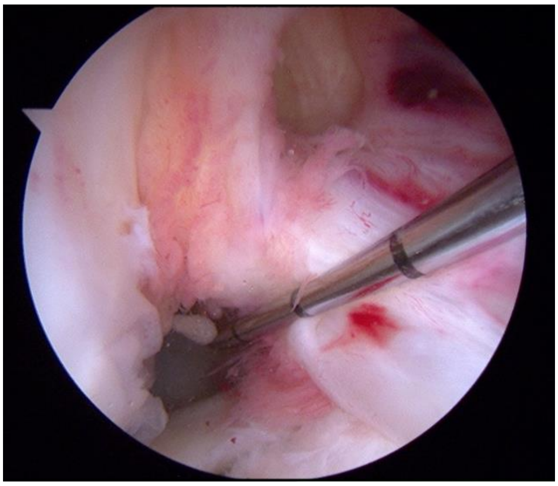

Figure 1.5 ACL tear from femoral insertion that has healed in a wrong position in the notch

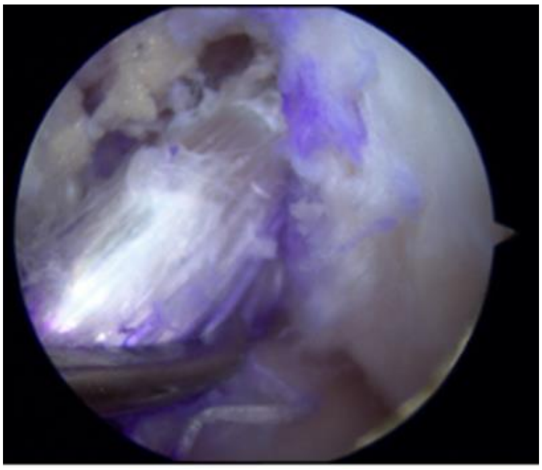

Figure 1.6 ACL graft in place

1.1.1 Biomechanics

The ACL is not isometric in flexion and extension. This change in length between the AM and PL bundles plays a role in the stability of the knee joint. The AM bundle is less tense between $0 - 30°$of flexion and tension increases from $30 - 130°$ of flexion. In contrast, the PL bundle is less tense in extension and progressively relaxes to 90° flexion, thereafter tensing again. The ACL offers antero-posterior stability of the knee joint. The PL bundle prevents anterior translation of the tibia from $0 - 30°$ flexion and then the AM bundle takes over thereafter. The ACL also gives rotatory stability with the PL bundle having a greater impact on rotation due to its lateral position on the tibia[8, 9].

With better understanding of ACL anatomy, the management of complete and partial tears has been revolutionised. Anatomic double bundle techniques and remnant preservation reconstruction have biomechanical, vascular and proprioceptive advantages to the patient.

1.1.2 MRI appearance

On MRI the ACL is a hypointense band-like structure. Primary signs of an ACL tear are focal discontinuity, wavy contour, hyperintensity, oedematous mass-like appearance or complete absence of the ligament[10,11,12].Secondary signs of ACL tear are anterior tibial translation (> 5 mm), deep sulcus sign (an irregular appearing lateral femoral sulcus with a depth of > 2 mm), pivot shift bone contusion pattern (lateral femoral condyle and posterolateral tibial plateau), a Segond fracture (capsular avulsion injury fracture of the lateral tibial plateau), buckling of PCL and uncovered posterior horn of lateral meniscus[11,12]. Figures 1.7 to 1.9 below show the MRI appearances of anterior and posterior cruciate ligaments.

Figure 1.7 MRI image of intact anterior cruciate ligament

Figure 1.8 Partial ACL tear. Note the haemarthrosis and bone bruises in the femur and tibia

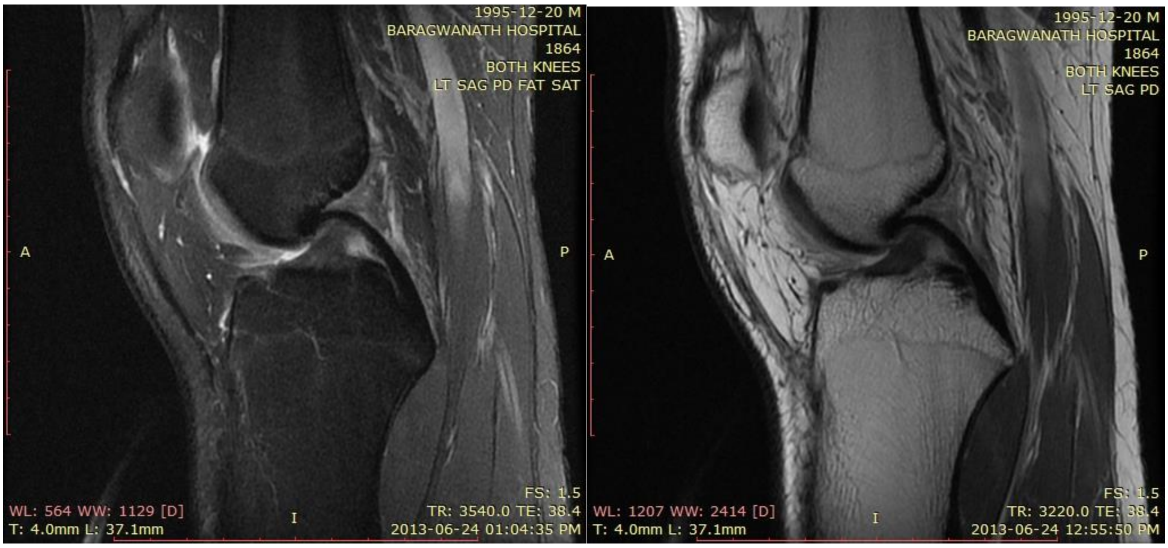

Figure 1.9 Intact posterior cruciate ligament

1.2 THE MENISCUS

The menisci are two structures previously thought to be vestigial but later proved after seminal work by Fairbank to play an important role in the function of the knee joint. Embryologically, the menisci arise from a condensation of the intermediate layer of the mesenchymal tissue surrounding the joint capsule. The characteristic shape of the lateral and medial menisci is achieved between the 8th and 10th week of gestation[13].

The menisci are semilunar and wedge shaped with concave upper and flat lower surfaces. These blend with their respective contrasting tibio-femoral surfaces to offer a congruent articulation. The menisci are attached to the joint capsule in their convexities. Strong insertional ligaments called entheses attach the meniscal horns to the tibia. This firm attachment is vital in the load distribution function of the meniscus. The anterior insertional ligament of the medial meniscus (MM) inserts into the anterior intercondylar fossa of the tibial plateau approximately 6 – 7 mm anterior to the ACL. The posterior insertional ligament of the MM attaches to the posterior intercondylar fossa between the posterior entheses of the lateral meniscus (LM) and the posterior cruciate ligament (PCL). The anterior insertional ligament of the LM attaches anterior to the lateral tibial spine/intercondylar eminence just behind the ACL. The posterior insertional ligament attaches posterior to the lateral tibial spine/ lateral intercondylar eminence anterior to the posterior enthesis of the MM. Both menisci are attached to each other anteriorly by the transverse ligament. The insertional ligaments are uncalcified fibrocartilage that gradually becomes calcified as it inserts into bone[13, 14]. See Figures 1.10 to 1.14 showing arthroscopic appearance of the menisci.

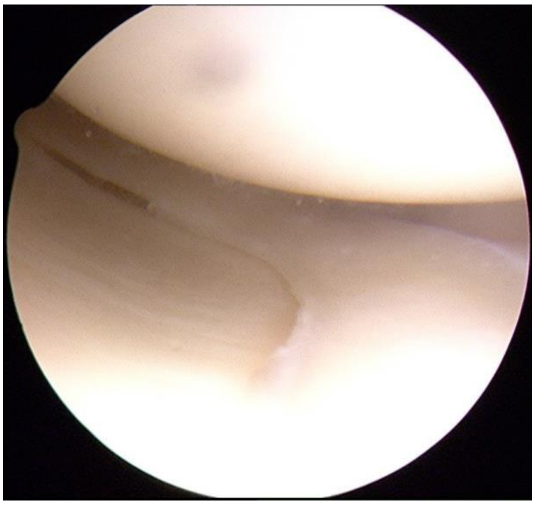

Figure 1.10 Arthroscopic appearance of a normal meniscus

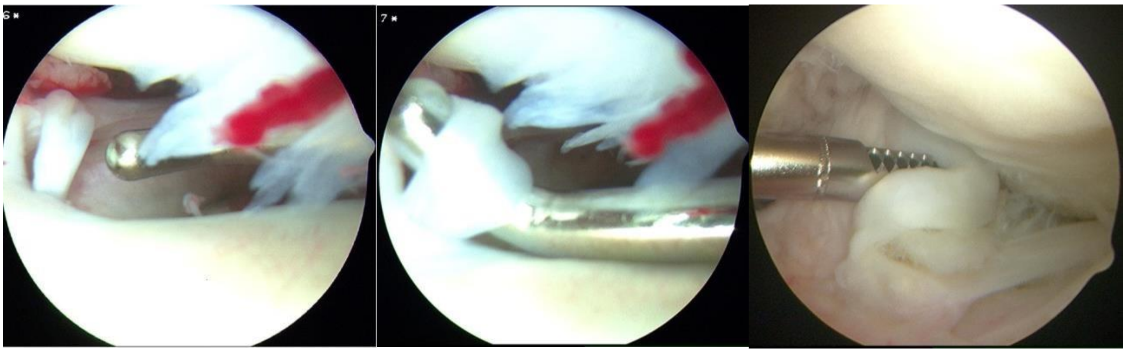

Figure 1.11 Arthroscopic appearance of bucket handle meniscal tear

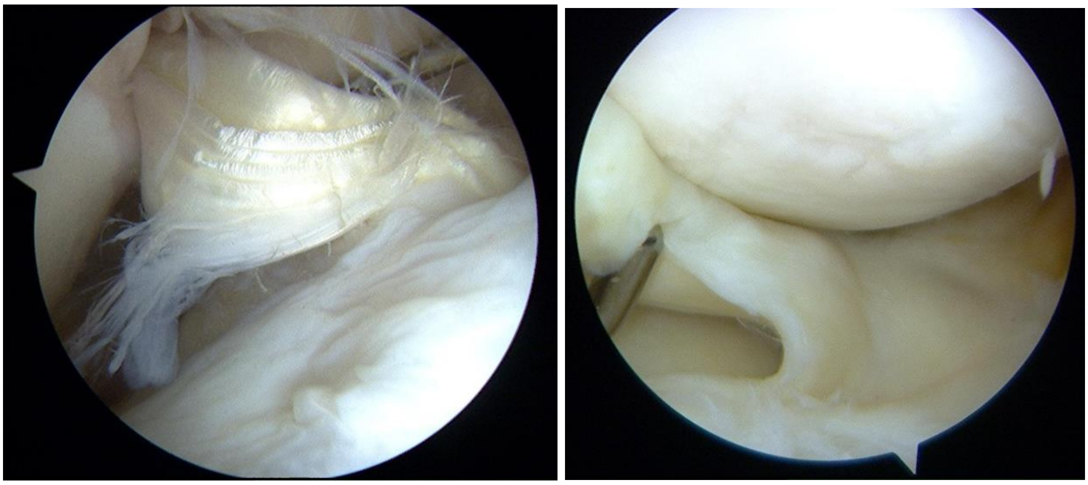

Figure 1.12 Meniscal tears with corresponding cartilage degeneration

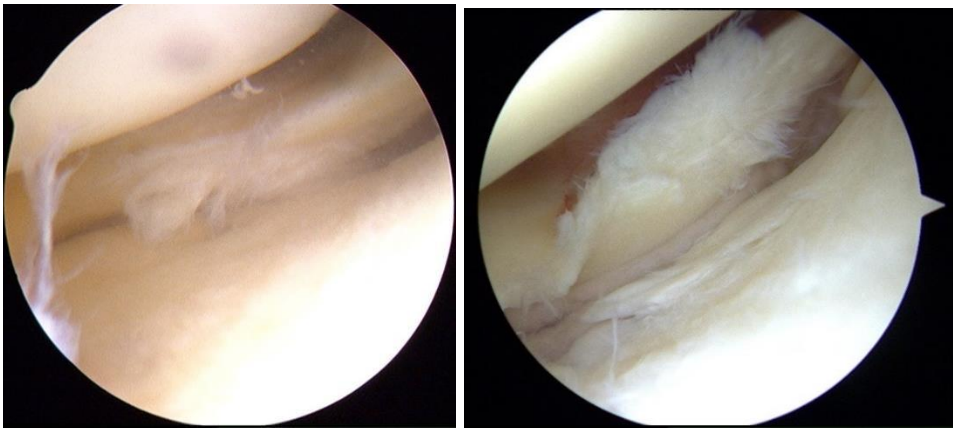

Figure 1.13 Meniscal degeneration and articular cartilage degeneration

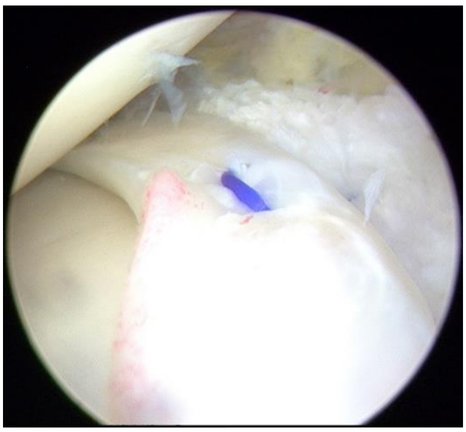

Figure 1.14 Repair of meniscus

1.2.1 Biomechanics

An important caveat to the understanding of meniscal biomechanics lies in the fact that the meniscus body-entheseal unit is a unique and complete structural-functional entity. Upon axial loading, forces are transmitted by the elaborate network of collagen fibres in the meniscus. Radial collagen fibres hold the longitudinal collagen bundles thereby converting the forces into hoop stresses at the meniscal periphery effectively creating even load distribution. Intact insertional ligaments prevent extrusion of the meniscus, which if unhindered leads to direct cartilage contact and subsequent degeneration. In addition, the menisci play a role in shock absorption, joint lubrication and stabilisation.

1.2.2 Composition

The menisci are composed of 72% water, 22% collagen, 0.8% glycosaminoglycans and 0.12% DNA. Cells in the menisci resemble fibroblasts and chondrocytes and have been aptly referred to as fibrochondrocytes. Type 1 collagen bundles are predominantly arranged in a circumferential pattern and held by radial fibres that serve as ties. The latter prevent longitudinal splitting of the meniscus. The configuration plays a role in the transmission of hoop stresses. The rest of the matrix consists of collagens (II, III, and V), proteoglycans and glycosaminoglycans.

1.2.3 Blood supply

In utero and at birth the menisci are vascularised but vascularity decreases with age. The lateral and medial genicular arteries form a peri-meniscal capillary plexus that has radial branches entering the outer third of the meniscus. The horns have a greater blood supply than the body.

1.2.4 Nerve supply

The menisci are innervated by a peri-articular plexus from the posterior articular and medial articular nerves. Similar to blood supply, innervation is more in the horns than the body. Mechanoreceptors, Golgi-type (III) endings, free nerve endings, myelinated and unmyelinated nerve fibres have been demonstrated in some cases extending up to the middle third of the meniscal body. Therefore, the menisci and their insertional ligaments have a role in proprioception and nociception.

1.2.5 MRI appearance

The normal meniscus has a low signal intensity and a triangular cross-section in the sagittal and coronal planes. In the LM, the anterior and posterior horns have equal lengths whereas the anterior is shorter than the posterior in the MM. Direct signs of meniscal tear are hyperintense signal that extends to the articular surface in two image planes (two-slice-touch rule), displaced fragment and missing meniscal tissue. Indirect signs are subchondral oedema beneath a meniscus and the presence of a para-meniscal cyst[15-17]

Different signs are described for meniscal tears. The double-PCL sign refers to a bucket handle tear of the MM that is displaced into the intercondylar notch. The double anterior horn sign indicates a bucket handle tear of the LM that has flipped into the anterior aspect of the lateral compartment. The absent bow-tie sign indicates a meniscal fragment that has displaced and no longer sits in its normal position[16, 17].

Meniscal tears are graded as I and II when there is focal or linear regions of high signal that are confined to the substance of the meniscus respectively. Grade III tears are where the area of signal extends to the joint surface[19]. Figures 1.15 to 1.18 show various MRI images of the menisci and the appearance of bone oedema.

Figure 1.15 Sagittal PD weighted density MRI of an intact meniscus showing a normal bow tie sign

Figure 1.16 Sagittal PD and FS PD weighted sequences showing a horizontal tear of posterior horn of medial meniscus

Figure 1.17 Bucket handle medial meniscus tear. Note the absent bow tie (coronal) and double PCL (sagittal) signs consistent with a bucket handle medial meniscus tear. Arrow shows the double PCL sign.

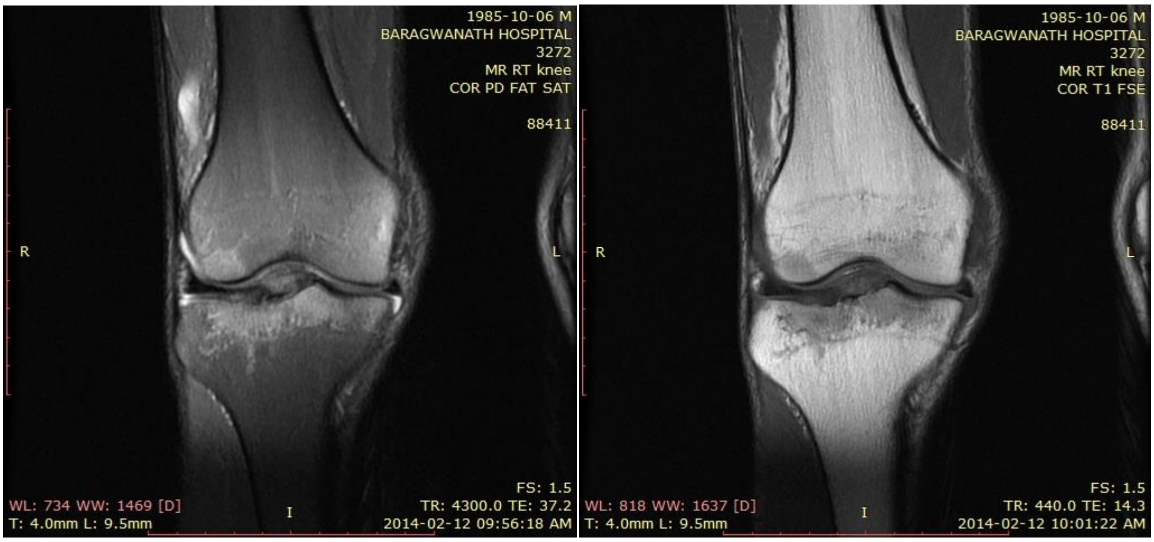

Figure 1.18 Fat suppressed coronal PD and T1 weighted images demonstrating tibial and femoral bone marrow oedema

1.3 MOTIVATION AND OBJECTIVES OF THE STUDY

1.3.1 Motivation for the study

Ligamentous knee injuries may be difficult to diagnose clinically and MRI may offer guidance in formulating an appropriate management plan. The validity of MRI diagnostic findings for ligamentous knee injuries in our setting is unknown. Furthermore, our patients wait for prolonged periods before having surgery and it is unknown if the MRI result is still valid. With this in mind we set out to answer some questions. How valid are MRI diagnoses for soft tissue knee injuries in our setting? Does the diagnostic validity of MRI differ between patients with different time intervals from MRI to surgery?

1.3.2 Research question

Do MRI findings correlate with arthroscopic findings in patients with anterior cruciate ligament and meniscal tears?

1.3.3 Study objectives

1.3.3.1 Primary objectives

To determine the validity of MRI as a diagnostic modality in the evaluation of intraarticular soft tissue knee injuries by means of calculating sensitivity, specificity, accuracy, positive and negative predictive values. The study will specifically focus on ACL and meniscal injuries.

1.3.3.2 Secondary objectives

1) To determine the profile of patients with ACL and meniscal injuries (gender, knee preponderance, mechanism of injury, duration of symptoms, time interval from MRI to arthroscopy).

2) To determine the effect of time interval from MRI to surgery on the diagnostic accuracy.

1.4 ETHICS

Approval for the study was granted by the University Human Research Ethics Committee (study reference number **M150631**) and the Chris Hani Baragwanath Hospital Medical Advisory Committee (see Appendix A).

CHAPTER TWO: MATERIALS AND METHODS

2.1 Design

This was a retrospective study of consecutive patients who had knee MRI done followed by arthroscopy at Chris Hani Baragwanath Academic Hospital Orthopaedic Department between April 2009 and March 2015.

Only patients operated on by two experienced Orthopaedic surgeons or by registrars under their direct supervision were included. One of the surgeons is fellowship trained in knee surgery. The surgeons had access to MRI reports prior to the operation.

The radiologists had clinical information provided on the MRI request forms. This information included the history of the complaint, physical examination findings and a differential diagnosis. Interpretation was done by a consultant working with a registrar, with the former giving the final verdict.

2.2 Case selection

2.2.1 Inclusion criteria

- All patients between 16 to 60 years of age who had knee MRI followed by arthroscopy for diagnosis and or treatment of intra-articular soft tissue knee injuries.
- MRI should have been done prior to surgery
- Arthroscopy performed by two orthopaedic surgeons (SKM and CT) or by registrars under their direct supervision. Direct supervision will be performance of the arthroscopy in the physical presence of the consultant orthopaedic surgeon. The consultant may be scrubbed for the procedure and recorded as an assistant.

2.2.2 Exclusion criteria

- More than one major trauma event
- Peri-articular knee fractures except tibial spine avulsion
- Previous surgery to the knee
- Established degenerative diseases e.g. osteoarthritis or rheumatoid arthritis
- MRI done outside CHBAH, since we wanted to maintain consistency
- Incomplete clinical data. (Please refer to Appendix B Data collection sheet template for the data to be captured).
- Arthroscopy done by any other surgeon besides SKM and CT.

2.3 Diagnostic criteria

Arthroscopy: Arthroscopic findings were the baseline against which MRI was validated. This is because it allows direct visualisation of intra-articular structures. The surgeon can probe the ACL or menisci to test their integrity. An arthroscope with 30° angle was used with standard entry portals. The 30° angle lens offers a wider field of view than a 0° lens but less than a 70° lens. A lens with a wide field of view allows better visualisation of intra-articular structures. For purposes of analysis each meniscus or ACL was classified as intact or torn. Degeneration or fraying was considered as no tear (intact). Cases where ACL laxity or partial tear were diagnosed but no ACL reconstruction was done were considered intact.

MRI: A 1.5 Tesla MRI machine (General Electric Echo speed HD) was used throughout the study period. MR imaging protocol included sagittal T1/T2/PD FS, axial T1/T2/PD FS and coronal T1/PD FS. For the purposes of analysis grade 2 meniscal tears, indeterminate or equivocal conclusions, “strain” and “tear could not be excluded” were considered as intact[11, 20, 21]. T1 weighted images show the best anatomy and T2 weighted images demonstrate pathology. PD weighted images are halfway between T1 and T2 and thus show both anatomy and pathology.

2.4 Data collection

Relevant data was collected from review of theatre records, patient files and radiology department archives for MRI reports. Composite data were tabulated in a standard data collection sheet. See appendix B for data collection sheet. Patients were assigned unique identification numbers in order to maintain confidentiality

CHAPTER THREE: DATA ANALYSIS

Data analysis was done for each knee and is presented in a flow diagram in keeping with the Standards for Reporting Diagnostic Accuracy (STARD) guidelines. The STATA version 13.1 statistical package was used for data analysis. Descriptive statistics were used to analyse the demographic profile of the participants. Non-parametric tests (Mann-Whitney and Kruskall-Wallis) and logistic regression models were used to analyse variables influencing the time interval from MRI to surgery. MRI and arthroscopic findings were classified as positive or negative according to the presence or absence of a tear respectively. Results were further analysed to determine true positives or negatives and false positives or negatives.

A true positive (TP) was when the MRI correctly identified a tear. A true negative was when the individual did not have a tear and the MRI tested negative for a tear. A false positive (FP) was when the MRI incorrectly identified a tear. A false negative (FN) was when the MRI incorrectly excluded a tear.

Sensitivity, specificity, accuracy, positive (PPV) and negative (NPV) predictive values were calculated using 2 x 2 contingency tables and the following formulae.

The chi-square test was used to calculate the Matthews Correlation Coefficient (MCC) to determine the correlation between MRI and arthroscopic findings.

Table 3.1 2 x 2 contingency table

		Arthroscopy(gold standard)	
		Positive(torn)	Negative(intact)
MRI	Positive (torn)	TP	FP
	Negative (intact)	FN	TN

Table 3.2 Formulae for calculating measures of diagnostic validity

Value	**Calculation**
Sensitivity	TP/ (TP+FN) x100
Specificity	TN/ (TN+FP) x100
PPV	TP/ (TP+FP) x100
NPV	TN/ (TN+FN) x100
Accuracy	TP+TN/ (TP+TN+FP+FN) X100
MCC	$\sqrt{(\chi^2/n)}$

A simple explanation of the above terms is given by Kostov et al. (2014)[22].

Sensitivity is how good the test is at detecting an ACL or meniscal tear

Specificity is how good the test is at identifying a normal knee

PPV is how often a patient with a positive test has an ACL or meniscal tear

NPV is how often a patient with a negative test does not have an ACL or meniscal tear

Accuracy is the proportion of test which correctly identifies ACL or meniscal tears.

The MCC is a measure of correlation of binary data. It is value between +1 and -1. A value of +1 indicates perfect agreement and conversely a value of -1 indicates total disagreement between prediction and observation. An MCC of zero is a prediction no better than random.

The estimation of statistical significance was set at $p \leq 0.05$.

CHAPTER FOUR: RESULTS

4.1 Patient sampling

The method of selecting the sample for inclusion in the study is shown Figure 4.1 below.

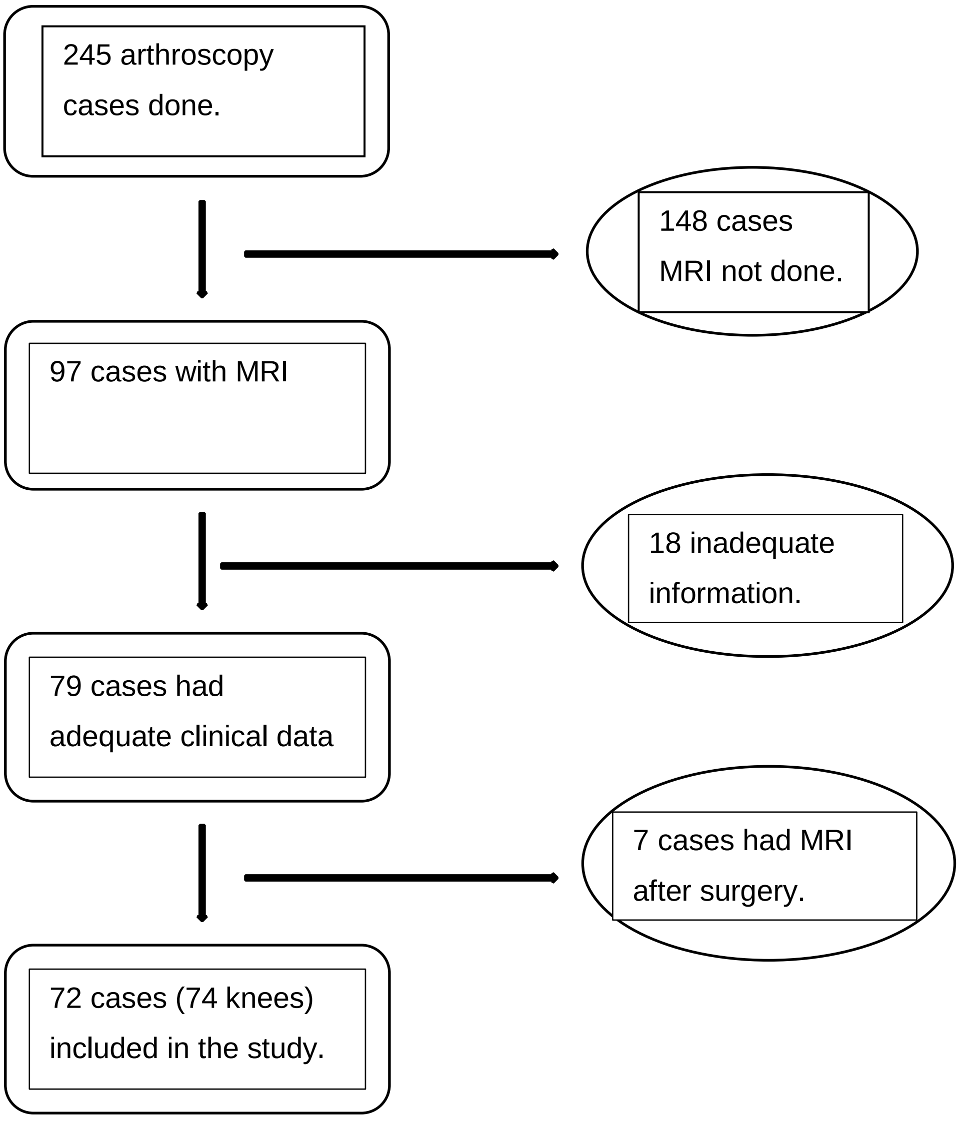

Figure 4.1 STARD flow diagram

4.2 General findings

There were 41(56.9%) females and 31(43.1%) males. Two males had both knees operated on. Median age was 35 years (IQR 26 - 43). There was a significant difference between males and females 28 years *vs* 41 years (p = 0.0019). The right knee was affected in 66.2% of cases. Median duration of symptoms was 48 weeks and there was no difference between both sexes. Modes of injury were grouped into 5 categories namely, traffic accident, falls, sports, other and not stated. Traffic accidents consisted of motor vehicle, pedestrian vehicle, motorcycle and train accidents. Sports related injuries were sustained from soccer, netball and rugby, with soccer predominating. Injuries classified as other were recurrent patella dislocations and assault. The mode of injury was not stated in 12 patients (16.2%). Overall, leading causes of injury were traffic accidents (32.4%), falls (27.0%) and sports (17.6%). There was a significant difference in the aetiology of knee injuries between males and females ($p < 0.05$). Traffic accidents and sports were the majority in males and in females falls were the leading cause. Refer to Table 4.1 overleaf for the demographic details of participants.

Table 4.1 Demographic details of participants

Characteristics	Overall (N = 72 knees) 74 patients	Male (n = 33 knees)	Female (n = 41knees)	*P* values
Age (years) *Median (IQR)*	35(26-43)	28(23-34)	41(32-47)	0.002*
Affected Knee *n* (%)				
Right	49(66.2)	23(69.7)	26(63.4)	0.570
Left	25(33.8)	10(30.3)	15(36.6)	
Duration of Symptoms (weeks) *Median (IQR)*	48(20-104)	40(23-54)	52(20-104)	0.630
Days between MRI and Surgery (weeks) *Median (IQR)*	71.5(29-143)	57(22-97)	83(40-239)	0.057
Mode of injury *n* (%)				
Traffic accident	24(32.4)	10(30.3)	14(34.2)	< 0.001*
Fall	20(27.0)	3(9.1)	17(41.5)	
Sport	13(17.6)	11(33.3)	2(4.9)	
Other	5(6.8)	1(3.0)	4(9.8)	
Not stated	12(16.2)	8(24.4)	4(9.8)	
MRI findings *n* (%)				
ACL tears	24(32.4)	12(36.4)	12(29.3)	0.520
MM tears	18(24.3)	9(27.3)	9(22.0)	0.600
LM tears	21(28.4)	12(36.4)	9(22.0)	0.170
Arthroscopic findings *n* (%)				
ACL tears	33(44.6)	19(57.6)	14(34.2)	0.044*
MM tears	17(23.0)	12(36.4)	5(12.2)	0.014*
LM tears	19(25.7)	11(33.3)	8(19.5)	0.180

*statistically significant

On both MRI and arthroscopy the ACL was the most commonly injured structure followed by the lateral and then the medial meniscus. Males had a significantly higher prevalence of ACL (57.6% *vs* 34.2% $p = 0.044$) and MM (36.4% *vs* 12.2% $p = 0.014$) tears on arthroscopy compared to females. There were 19 consultant radiologists and 24 registrars involved in interpreting the MRIs. Registrars were always paired with consultants and did not independently report MRIs.

4.3 Diagnostic validation of MRI

The sensitivity, specificity, accuracy and predictive values are tabulated below in Table 4.2.

Table 4.2 Percentage Sensitivity, Specificity, Positive and Negative Predictive values, Accuracy and Mathew's correlation coefficient (%)

	ACL	**MM**	**LM**
Sensitivity	63.6	58.8	52.6
Specificity	92.7	86.0	80.0
Positive predictive value	87.5	55.6	47.6
Negative predictive value	76.0	87.5	83.0
Accuracy	79.7	79.7	73.0
Matthews Correlation Coefficient	0.60	0.44	0.32

4.4 Time interval and diagnostic accuracy

Median time interval from MRI to arthroscopy was 71.5 days (IQR 29 − 143). Nonparametric tests were used to determine if there were any variables influencing the time interval between MRI and surgery. The Spearman coefficient showed that age and interval from MRI to surgery were independent (p = 0.8869). The Kruskall-Wallis test revealed a marginally significant difference between males and females in the number of days between MRI and surgery. Males tended to have earlier surgery compared to females with median waiting time of 57 days *vs* 83 days (p = 0.057). The Kruskall-Wallis test showed that there was no association between mode of injury and the time interval between MRI and surgery (p = 0.794). We used the Mann-Whitney test in order to determine if there was a difference between patients diagnosed with tears or with intact ligaments in their time interval to surgery. There was no significant difference in the days from MRI to surgery between those with or without ACL or meniscal tears on MRI (ACL p = 0.68, MM p = 0.54, LM p = 0.56). To correct for all confounders we ran a generalized linear regression model for all baseline pre-operative variables to see if they impacted on the time interval from MRI to surgery. None of the variables impacted on the time interval between MRI and surgery. Only 63 participants were in the model because the duration of symptoms was unknown in 11 participants. See Table 4.3 below.

Table 4.3 Generalised linear regression analysis of factors associated with Days between MRI and surgery (N = 63)

Days between MRI and Surgery	**Coef.**	***p* value**	**95% Confidence Interval**	
Age	-.3104248	0.861	-3.782957	3.162107
Sex				
Female	Base			
Male	-49.73861	0.198	-125.4155	25.93826
Duration of symptoms	.1368961	0.358	-.1550643	.4288565
Mode of injury				
Sport	Base			
Traffic accident	-87.37691	0.107	-193.5941	18.84029
Fall	-59.06728	0.312	-173.4848	55.35027
Other	-170.7019	0.101	-374.4965	33.09266
Not stated	-114.8785	0.068	-238.4154	8.658472
MRI diagnosis ACL				
Torn	Base			
Intact	33.58245	0.374	-40.48907	107.654
MRI diagnosis MM				
Torn	Base			
Intact	38.2967	0.357	-43.22066	119.8141
MRI diagnosis LM				
Torn	Base			

Intact	11.27153	0.784	-69.43773	91.98078

To determine the effect of time interval from MRI to surgery on the diagnostic accuracy of MRI we divided the patients into three groups. These we named early, intermediate and late intervention groups. The early group had arthroscopy done within a period of less than or equal to 6 weeks (42 days). The intermediate group had arthroscopy in a period between 6 and 16 weeks. The late group had arthroscopy at a period greater than 16 weeks from having an MRI. Multinomial logistic regression analysis showed that there was no significant difference in baseline characteristics of the groups. Refer to Table 4.4 below.

Table 4.4 Multinomial logistic regression analysis of factors associated with Days between MRI and surgery in the early, intermediate and late intervention groups (N = 63)

	Days between MRI and Surgery	**RRR**	***p* value**	**95% Confidence Interval**	
Early	**Age**	.9956121	0.903	.9273307	1.068921
	Sex				
	Female	Base			
	Male	.6205248	0.56	.1249174	3.082446
	Duration of symptoms	.9955331	0.431	.9844929	1.006697
	Mode of injury				
	Sport	Base			
	Traffic accident	.6459847	0.694	.0731353	5.705809
	Fall	1.312748	0.818	.1294802	13.30942
	Other	9700606	0.990	0	.
	Not stated	1.929024	0.610	.1546138	24.06728
	MRI diagnosis ACL				
	torn	Base			
	intact	.556521	0.430	.1299663	2.383045
	MRI diagnosis MM				
	torn	Base			
	intact	.8691949	0.865	.1732439	4.360902
	MRI diagnosis LM				
	torn	Base			
	intact	2.162239	0.364	.4094527	11.41836

Intermediate	Base outcome				
Late	**Age**	.9956121	0.903	.9273307	1.068921
	Sex				
	Female	Base			
	Male	.6205248	0.560	.1249174	3.082446
	Duration of symptoms	.9955331	0.431	.9844929	1.006697
	Mode of injury				
	Sport	Base			
	Traffic accident	.6459847	0.694	.0731353	5.705809
	Fall	1.312748	0.818	.1294802	13.30942
	Other	9700606	0.990	0	.
	Not stated	1.929024	0.610	.1546138	24.06728
	MRI diagnosis ACL				
	torn	Base			
	intact	.556521	0.430	.1299663	2.383045
	MRI diagnosis MM				
	torn	Base			
	intact	.8691949	0.865	.1732439	4.360902
	MRI diagnosis LM				
	torn	Base			
	intact	2.162239	0.901	.0253093	65.2075

The diagnostic accuracy for only ACL and LM injuries seemed to change in these three groups, being highest for the intermediate group. See Table 4.5 overleaf.

Table 4.5 Comparison of percentage diagnostic accuracy of MRI in the early, intermediate and late intervention groups (%)

		Early **(≤ 6 weeks)**	Intermediate **(6 − 16 weeks)**	Late **(> 16 weeks)**
Accuracy %	ACL	70.8	92.6	73.9
	MM	75.0	81.5	82.6
	LM	62.5	81.5	73.9

The accuracy of MRI seemed to change for ACL and LM only. It was highest in the patients who had intermediate intervention. This suggested an intrinsic change within the participants as time elapsed. We were then prompted to perform a qualitative analysis of the sub-groups. We determined the prevalence of false positives and negatives and the overall prevalence of tears discovered at arthroscopy. Indeed the prevalence of false positives and false negatives differed as time elapsed from doing an MRI. These changes were more marked for ACL and LM injuries. See Table 4.6 below.

Table 4.6 Percentage prevalence of false positives and false negatives in early, intermediate and late intervention groups (%)

		Early	**Intermediate**	**Late**
ACL	False positives	4.17	0	8.70
	False negatives	25.0	7.41	17.4
MM	False positives	12.5	11.1	8.70
	False negatives	12.5	7.41	8.70
LM	False positives	16.7	7.41	21.7
	False negatives	20.8	11.1	4.45

Despite there being no significant differences in the baseline characteristics in the 3 groups as shown by the multinomial regression model, there is a difference in the prevalence of tears diagnosed at arthroscopy. Table 4.7 below shows this temporal variation in the prevalence of tears.

Table 4.7 Prevalence of tears diagnosed at arthroscopy in the early, intermediate and late groups

	ACL	**MM**	**LM**
Early N(%)	14(58.3)	6(25.0)	7(29.1)
Intermediate N(%)	10(37.0)	7(25.9)	9(33.3)
Late N(%)	9(39.1)	4(17.4)	3(13.0)

CHAPTER FIVE: DISCUSSION

The objectives of this study were to determine the profile of patients with soft tissue knee injuries and the diagnostic validity of MRI findings. In addition, our aim was to ascertain the effect of time interval from MRI to surgery on the accuracy of MRI. The age disparity between males and females stands out in this study. Females with soft tissue knee injuries tended to be older than males. The overall leading cause of injury in both sexes was road traffic accidents (32.4%). This is a worrying trend as it reminds us of South Africa's high burden of road traffic related injuries that are twice the global average rate[23]. The modes of injury were also significantly different with males suffering higher energy injuries from traffic accidents and contact sports. This is in keeping with the higher prevalence of traffic accidents in young males and their active sporting lifestyle. Females mostly suffered low energy falls closely followed by traffic accidents. There was a low prevalence of sports related injuries in females. This is probably because they engage in less sporting activities especially in this older cohort.

The time interval from MRI to surgery was wide ranging from 1 to 676 days. This is much longer than in the study by Chen et al. (2014) (mean 10.2 days, range 2 − 30 days) [18]. Males tended to have earlier surgery than females although this was of marginal significance (median 57 days *vs* 83 days $p = 0.057$). This is probably because they are younger and the surgeons felt they would benefit more from surgery compared to the females. In addition, their propensity to suffering from high energy trauma may have influenced surgeons to treat them earlier than females. Interestingly, the MRI result did not have an influence in the timing of surgery. It would have been more likely that patients with positive findings would have had a shorter time to surgery interval. This finding shows that there are probably other factors that the surgeons considered in deciding when to operate. One likely factor would be the presence of supporting clinical findings in addition to the MRI report.

ACL injuries were more prevalent than medial and lateral meniscal injuries. This finding is similar to other studies[10, 24]. However in our study LM tears were more prevalent than MM tears. ACL and MM tears were significantly more prevalent in males than in females. The mode of injury could offer a possible explanation in that males suffered more high energy knee trauma making them more likely to sustain ACL and MM tears than the females.

Table 5.1 overleaf compares the measures of diagnostic validity of our study to other studies.

Table 5.1 Comparison of measures of diagnostic validity in different studies (%)

Studies		**Sensitivity**	**Specificity**	**PPV**	**NPV**	**Accuracy**
Kostov et al. 2014, (103 patients)	ACL	83	88.37	93	74.5	82.5
Bari et al. 2014, (71 patients)	ACL	87.87	81.57	80.55	88.57	
	MM	93.54	87.5	85.29	94.59	
	LM	77.77	81.81	72.41	85.71	
Crawford et al. 2007, (systematic review of 43 studies)	ACL	86.5	95.2	82.9	96.4	93.4
	MM	91.4	81.1	83.2	90.1	86.3
	LM	76	93.3	80.4	91.6	88.8
Our study, 2017 (74 cases)	ACL	63.6	92.7	87.5	76.0	79.7
	MM	58.8	86.0	55.6	87.5	79.7
	LM	52.6	80.0	47.6	83.0	73.0

Our study shows that MRI is more sensitive at identifying ACL tears than meniscal tears. However for all the three intra-articular structures of interest the specificity is higher than the sensitivity. This means that MRI is better at identifying intact ACLs or menisci than torn ones. Furthermore, the NPV of menisci is much higher than the PPV. Therefore MRI may be used as a preoperative test to identify normal knees and thus avoid unnecessary arthroscopies.

The diagnostic accuracy in our study compares favourably to other studies shown in table 5.1. The values in Crawford et al. (2007) study are marginally higher probably because most articles in their systemic review were prospective studies[25].

In our study there were many radiologists involved in interpreting the MRIs. This creates a lot of inter-observer variability which reduces the power of the study. Similarly, Ha et al. (1998) had 12 radiologists and numerous fellows and residents and the authors point out the same challenge[11]. However they contend that the presence of many radiologists and arthroscopists is representative of the general clinical setting at large and we concur with this point. In our study general radiologists interpreted the MRIs. Studies that involve musculoskeletal radiologists have higher measures of diagnostic reliability. Chen et al. (2014) and Navali et al. (2013) report that the level of experience of the radiologist has an impact on the accuracy of interpretations[18, 24].

The specificity and NPV for meniscal injuries is higher than sensitivity and PPV thus rendering MRI reliable in excluding tears. In contrast, the higher PPV for ACL injuries makes MRI reliable at diagnosing ACL injuries. A patient given the result of an ACL tear would deem the result reliable.

To determine the effect of time interval from MRI to surgery on the diagnostic accuracy of MRI we divided the cohort into three groups. The rationale for the time intervals was based on our local definition of early surgical intervention being at less than 6 weeks from injury. The upper limit for intermediate is based on healing periods for meniscal injuries in the avascular and vascular zones which are at 16 and 13 weeks respectively[14]. We admit that the time interval from MRI to surgery is not synonymous with the duration of symptoms from injury. However, setting these differential periods would ensure that we separate any ACLs or menisci that would heal or degenerate as the patient waited for surgery.

The accuracy of MRI seemed to change for ACL and LM only. It was highest in the patients who had intermediate intervention. This suggested an intrinsic change within the participants as time elapsed since the multinomial regression model did not show any differences in the baseline characteristics of the 3 subgroups. Qualitative analysis of the subgroups indeed showed that the prevalence of false positives and false negatives differed as time elapsed from doing an MRI. These changes were more marked for ACL and LM injuries.

These changes in FP and FN rates are responsible for the change in accuracy. The determination of whether a finding is true or false is made intra-operatively and the MRI diagnosis is always constant. A change in FP and FN rates is suggestive of a change in the morphological state of the ACL or menisci with time. When FN rate decreases, TN rate increases and when FP rate reduces, the TP rate increases. Assuming that MRI was 100% accurate then a decrease in FN rate indicates healing of tears and an increase in FN rate indicates development of tears. Conversely, a decrease in FP rate indicates development of tears and an increase in FP rate signifies healing of tears. This holds with the presupposition that the patients do not sustain another injury when awaiting surgery.

Therefore we note in our results that there might be healing of some ACL tears over the 6 week period as the patients await surgery as shown by the drop in FN rates between the early and intermediate groups. For the LM there is also a suggestion of healing of tears as shown by the consistent fall in the FN rate in all 3 groups. However for the ACL there is a rise in FP and FN rates after the 6 − 16 week interval suggesting both healing and development of tears in different patients respectively. The FP and FN rates for MM do not mirror the changes seen with those of ACL and LM. The changes in FP and FN rates in the different intervals show both combined healing and development of tears in the MM to a lesser extent.

We conclude that the diagnostic accuracy of MRI changes with time especially for the ACL and LM. The fact that there was no statistically significant difference in delay to surgery for patients with positive or negative MRI findings lends credibility to our assertion. Chen et al. (2014) argue that the time interval between MRI and surgery should be shortened in order to eliminate false positives[18]. Expanding the point further he reports that injuries in the vascular zone of the meniscus may heal as the patient waits for surgery. However, the results of Kleinrok et al. (2013) were different to ours[7]. They found no difference in the indicators of validity of MRI both for acute and chronic injuries and also for delay between MRI and surgery. However in their study they defined acute and chronic injuries as less than or greater than 6 weeks respectively. Furthermore, they defined early surgery and late surgery as less or greater than 30 days from having an MRI. These time periods are not sufficiently long enough to allow for healing or degeneration of menisci and therefore do not fairly create two independent groups. Our study is unique in that we divided participants into intervals expected for spontaneous resolution of meniscal tears in accordance with literature[14].

5.1 STUDY LIMITATIONS

This is a retrospective study and it is subject to limitations in record keeping. It was not possible to find MRI and admission records for all patients. In addition the study is subject to interpretation bias by the researcher when reviewing the operation notes because there was no standardized way of reporting of arthroscopy findings. There may have been selection bias of those participants who were sent for MRI before surgery compared to those who went directly for surgery. The patients who went directly for surgery might have been clear cut cases and the difficult cases were sent for MRI. The study also suffers from incorporation bias in that the surgeons had prior knowledge of the MRI result and that may influence intraoperative diagnosis. The study also assumes that arthroscopy is 100% accurate. This is not true because it is a technically demanding procedure and tears in hard to reach areas may be missed. The study sample is also small and may not be representative of the many cases that have arthroscopies. In addition there are many patients who have MRI done and do not have surgery.

5.2 CONCLUSION

This study shows a positive correlation between MRI and arthroscopic findings for anterior cruciate and meniscal injuries. Furthermore it shows a time dependent change in diagnostic accuracy of MRI for ACL and LM injuries which is probably a result of healing and development of some tears.

5.3 FUTURE RESEARCH

A randomized controlled trial to determine the relationship between diagnostic accuracy and the time interval from MRI to surgery should be done. The effect of duration of injury on the diagnostic accuracy may also be investigated. This will help in determining if there is a relationship in chronicity of tears and our ability to detect them. The biology of healing of ACL and meniscal tears should be studied so that we may better understand the natural history of these tears. This will impact on the timing of MRI investigations and arthroscopic intervention.

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APPENDICES

A: Human Research Ethics Clearance certificate

B: Data Collection sheet

Appendix A: Human Research Ethics Clearance certificate

R14/49 Dr Thando Ncube

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M150631

NAME: (Principal Investigator) Dr Thando Ncube

DEPARTMENT: Orthopaedics
Chris Hani Baragwanath Academic Hospital

PROJECT TITLE: Correlation of Magnetic Resonance Imaging and Arthroscopic Findings in Patients with Soft Tissue Knee Injuries

DATE CONSIDERED: 26/06/2015

DECISION: Approved unconditionally

CONDITIONS:

SUPERVISOR: Prof Sebastian Keith Magobotha

APPROVED BY:
Professor P Cleaton-Jones, Chairperson, HREC (Medical)

DATE OF APPROVAL: 29/08/2016

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 10004, 10th floor, Senate House/2nd Floor, Phillip Tobias Building, Parktown, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in June and will therefore be due in the month of June each year.

Principal Investigator Signature

Date 12/02/18

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix B: Data collection sheet

DEMOGRAPHY						MRI RESULT				ARTHROSCOPY RESULT			
Patient code	Age	Sex	Affected knee	Mode of injury	Duration of symptoms	Date of MRI	ACL	MM	LM	Date of Surgery	ACL	MM	LM