SUDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF GRADUATE STUDIES

Characterization of Knee Joint Changes in Sudanese using Plain X-ray

توصيف تغيرات مفصل الركبة لدى السودانيين باستخدام الأشعة السينية التقليدية

A thesis submitted for the fulfilment of Ph.D. degree in Diagnostic Radiological Technology

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

الآية

قال تعالى: (وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ ۖ وَسَتُرَدُّونَ إِلَىٰ عَالِمِ الْغَيْبِ وَالشَّهَادَةِ فَيُنَبِّئُكُمْ بِمَا كُنْتُمْ تَعْمَلُونَ)

صدق الله العظيم

سورة التوبة الآية (105)

Abstract

This study was performed to characterize knee joint changes in Sudanese through measurement using plain x-ray in order to determine potential candidate for bone size and to estimate the artificial knee joint size before surgery. The study was conducted in two centres in Khartoum state they include: Modern Medical Centre and Antalya Medical Centre in the period from June 2012 to April 2015. The sample of this study consisted of **320** symptomatic knee joints patient. **257** of them were examined plain x-ray for knee **106** showed no changes in the x-ray film, their ages between (18-64) years and **151** patients showed changes of knee joint in the plain X-ray, their ages between (20-78) years. To estimate the artificial knee size before surgery **63** patients have an artificial knee joint in Sharg Elneel Hospital, Khartoum, Sudan, were collected, their ages between (59-74) years. The result of this study showed that: The height and circumference of the knee for males and females were significantly correlated. The height of the knees was increased by 0.39 cm and 0.29 cm per each cm of patient height for male and female. Similarly the circumference of the knee for male and female were associated with the height and weight of patient. The appearance of bony changes can be estimated using bone measurement. The mediolateral femur measurements for male is equal to 71.8 ± 2.5 and 67.8 ± 3.6 for female and the mediolateral tibia measurements is equal to 74.6 ± 3.2 for male and 69.3 ± 3.7 for female. These differences were significant at p=0.05 using the t-test with t=2.62 for male and t=3.07 for female and p=0.04 and 0.02 respectively. The size of artificial femur and tibia for male and female can be estimate using the following equation: for male; femur AFS= (0.73 x MLFS) - 42.5 and tibia ATS = (0.58 x MLTS) - 33.8. Similarly for female, femur AFS = (0.59 x MLFS) - 33.4 and tibia ATS = (0.48 x MLTS) - 27.1.

المستخلص

أجريت هذه الدراسة لتوصيف تغيرات مفصل الركبة لدى السودانيين من خلال قياسات لمفصل الركبة أخذت من الأشعة السينية التقليدية لمفصل الركبة لتحديد مرشح محتمل لتغيرات عظام المفصل وبالتالى تقدير حجم مفصل الركبة الأصطناعى قبل اجراء العملية .وقد أجريت الدراسة فى مركزين فى ولاية الخرطوم وهما المركز الطبى الحديث ومركز انطاليا الطبى فى الفترة من يونيو 2012م الى ابريل 2015 م. وتكونت عينة هذه الدراسة من عدد 320 من مفاصل الركبة التى تعانى أعراض آلام. وقد تم فحص 257 مريض بالأشعة السينية التقليدية .106 من المرضى لم يظهر لهم أى تغيرات في العظام فى صورة الأشعة (ركب طبيعية) تتراوح أعمارهم بين (18و64) و151 من المرضى ظهرت لديهم اعراض تغيرات فى مفصل الركبة (ركب مريضة) تتراوح أعمارهم بين (20 و78).لتحديد حجم الركبة الصناعى قبل العملية أخذت بيانات 63 مريض لديهم ركب صناعية بمستشفى شرق النيل الخرطوم- السودان وتتراوح أعمارهم بين (59و74). وقد خلصت الدراسة إلى النتائج الآتية:- أن إرتفاع ومحيط الركبة للذكور والأناث كانت مرتبطة الى حد كبير حيث أن ارتفاع الركبتيين يزيد بنسبه 0.39سم 0.29 سم فى كل سم من ارتفاع المريض للذكور والأناث على التوالى .وبالمثل محيط الركبة وجد انه مرتبط مع إرتفاع ووزن المريض. ويمكن تقدير ظهور تغيرات العظام بأستخدام قياس العظام . أن عرض عظم الفخذ (الخط الناصفى الوحشى) للذكور يساوى 6.4±1.03 و5.9 ±0.7 للاناث وقياس الساق (الخط الناصفى الوحشى) للذكور يساوى 6.8±0.9 و6.3 ± 0.6 للاناث. وكانت هذه الاختلافات كبيره فى الاحتماليه 50% (0.05) باستخدام اختبار(ت) 2.62 للذكور و3.07 للاناث والأحتماليه كانت تساوى 0.04 و0.02 على التوالى. قياس الفخذ الصناعي للذكر (قياس الخط الناصفي الوحشي للفخذ ×0.73) -42.5 ، قياس الساق الصناعي للذكر (قياس الناصفي الوحشي للساق× 0.58) -33.8 ، قياس الفخذ الصناعي للأنثى (قياس الخط الناصفي الوحشي للفخذ × 0.59) -33.4 وقياس الساق الصناعي للأنثى (قياس الخط الناصفي الوحشي للساق × 0.48) -27.1

Dedication

Dedication

To

My parents, sons (Mohamed and Sharaf Addeen)

Brother and sisters.

My colleagues and students.

And for all those who search for the knowledge, I dedicate this work.

With my love …

Acknowledgement

Acknowledgement

Grateful acknowledgement is made to my teacher, supervisor, ***Dr. Mohamed Elfadil Mohamed****, and Co-supervisor,* ***Dr. Salah Mohamed Abdulrahim****, whose farsighted and generous help has assisted greatly in the development of this study.*

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With all my love and thanks for my parents and family and ***Osman Sharaf Addeen Mohamed.***

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The researcher ….

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List of Abbreviations

The abbreviations	The meanings
BMI	Body Mass Index
OA	Osteoarthritis
JSW	Joint Space Width
L1	Lumbar Spine No.1
L4	Lumbar Spine No.4
S4	Sacrum No.4
ACL	Anterior Cruciate Ligament
PCL	Posterior Cruciate Ligament
AP	Anterosuperior
Kv.p	Kilo voltage peak
mAs	milli Amperage/second
FFD	Focal Film Distance
CT	Computerized Tomography
MRI	Magnetic Resonance Imaging
DVT	Deep Venous Thrombosis
U/S	Ultra Sound
mm	millimeter
CR	Computed Radiology
DR	Digital Radiology
Kg.	Kilogram
SD	Standard Deviation
FW1	Femur Width 1
FW2	Femur Width 2
FW3	Femur Width 3
FL1	Femur Length 1
FL2	Femur Length 2
FL3	Femur Length 3

TW1	Tibia Width 1
TW2	Tibia Width 2
TW3	Tibia Width 3
TL1	Tibia Length 1
TL2	Tibia Length 2
TL3	Tibia Length 3
AFS	Artificial Femur Size
ATS	Artificial Tibia Size
MLFS	Mediolateral Femur Size
MLTS	Mediolateral Tibia Size
3D	Three Dimension

Chapter One

Introduction

Chapter One

1.1. Introduction:-

Knee joint is one of the most important hinge joints of our body. We use our knee joints several times in a day. They are used when we sit, fold legs, run and walk or do any kind of leg movement. They connect the lower leg to the rest of the body and gives stability, flexibility and strength. They support the legs to bear the body weight and also help in proper locomotion. Any disorder or defect in the knee bones can restrict the activities of the leg which can directly affect our locomotion (Cindy et al, 2014).

In Sudan to the knowledge of the author there is no sufficient data published locally or internationally regarding the knee joint measurement or significance of gender or even occupation in knee measurement.

The main objective of the current study was to characterize the knee joints in Sudanese population using plain x-ray to explain the differences that arise in the knee joints measurements which might be attributed to body characteristic or pathological changes.

1.2. Knee measurements:-

X-rays are valuable for detecting abnormalities in bone and are taken to evaluate painful, deformed, or suspected abnormal areas of bone. Often, x-rays can help to diagnose fractures, tumors, injuries, infections, and deformities (such as congenital hip dysplasia). Also, sometimes x-rays are helpful in showing changes that confirm a person has a certain kind of arthritis (for example, rheumatoid arthritis or osteoarthritis). X-rays do not show clearly soft tissues such as muscles, bursae, ligaments, tendons, or nerves. To help determine whether the joint has been damaged by injury, a doctor may use an ordinary (non-stress) x-ray or one taken with the joint under stress (stress x-ray) (Merck, 2010).

Unlike knee plain radiography which can only detect joint space narrowing and osteophytes, magnetic resonance imaging can directly visualize and analyze the whole knee structure, including bone size, cartilage defects and loss of cartilage volume. Tibial subchondral bone area expansion may be primary and it associated with risk factors such as age, body mass index (BMI), genetics and/or limb malalignment. It can lead to the development of knee defects, which may also be caused by demographic, anthropometric and environmental factors such as age, female sex, BMI and smoking as well as structural changes such as osteophytes, bone marrow lesions, meniscal tears, meniscal extrusion and ligament abnormalities. Once knee cartilage defects develop, they have a variable natural history but are associated with subsequent cartilage loss in a dose-response manner. Both tibial subchondral bone area and knee cartilage defects are quantitatively related to the severity of knee osteoarthritis (OA), and predictive of the need for knee joint replacement in subjects with knee OA independent of radiographic change. Taken as a whole, these studies suggest that tibial subchondral bone expansion and cartilage defect development represent important targets for the prevention of cartilage loss and joint replacement (Ding et al, 2007).

Gender differences could be reduced for cartilage volume and surface area when normalized to body weight and body weight x body height. The study demonstrates significant gender differences in cartilage volume and surface area of men and women, which need to be taken into account when retrospectively estimating articular cartilage loss in patients with symptoms of degenerative joint disease. Differences in cartilage volume are primarily due to differences in joint surface areas (epiphysial bone size), not to differences in cartilage thickness (Faber et al, 2001).

Measurement of joint space width (JSW) from plain radiographs is widely considered the best available surrogate criterion to assess the progression of osteoarthritis (OA) in clinical trials and epidemiological studies. OA progresses slowly and joint space narrowing varies from 0.1 to 0.6 mm/year Many efforts have been made to improve the reliability of joint space assessment, particularly the choice of the measuring instrument, that of the site of measurement and the quality of reading (training session, centralized reading). In contrast, the influence of patient positioning and of the radiographic procedure has never been carefully studied, except for the influence of weight bearing. According to some authors, slight changes in patient positioning or radiographic procedure may modify JSW and compromise the reliability of measurements. Fife et al. found that JSW in a normal volunteer decreased by 17% when the X-ray beam was lowered by 1 cm below its original alignment initially centered at the midpoint of the patella. (Karen et al, 2008)

They also found that with 10° flexion the medial joint space width decreased by 25% compared to 0° flexion. Lynch et al. studied the influence of knee position in five post-mortem subjects and found that the error of JSW measurement was ~0.15 mm/10° of internal or external rotation of the knee joint. Therefore, standardization of patient positioning and radiographic procedure seems necessary, particularly for the quantitative assessment of JSW. However, in many studies there is no standardization of the radiographic procedure or of patient positioning. The knees are generally radio graphed standing, with the joint in a fully extended position, but X-ray beam inclination or direction are rarely specified. In other studies, the X-ray beam was horizontal or parallel to the joint surface and directed at the midpoint or the lower pole of the patella. (Karen et al, 2008)

Evaluations of knee alignment are useful in the diagnosis of arthritic conditions affecting the knee joint, serving also as a guide for conservative management and surgical planning. They are also fundamental to various aspects of musculoskeletal research. Recently, there has been great interest in frontal plane alignment measures related to the pathogenesis of knee osteoarthritis (OA). Several approaches have been proposed over the years to describe and measure alignment, but the differences between them have made it difficult to compare or correlate the results of independent studies. Toward a standard approach to the measurement and reporting of alignment data that may be equally applicable to clinicians and researchers, we discuss a system of measurements based on geometric analysis of the femur, tibia and knee joint surfaces. We also discuss a standardized methodology for measurement and computation of these parameters (T Derek et al, 2007)

1.3. Problem of the study

The knee joint is a vital joint in the body which is crucially associated with walking and movement activities. Therefore specific characterization of the size of the knee joint changes due to age, weight and duration of disease as well as gender differences and estimation of the artificial bone size will facilitate an objective evaluation of knee changes, which will lead to a remarkable improvement of knee assessment and management.

1.4. Significant of the study

This study will give measurement of knee joint without bone changes and those with bone changes and hence objectively classify the symptomatic patient with changes manifested in the x-ray from those without changes shown in the x-ray. Also it will facilitate the knowledge of differences between male and female in respect to knee joint measurement. In the same essence it will help in estimating the artificial knee size components before the surgery rather than what happing now.

1.5. Objectives of the study

The general objective of this study was to characterize the knee joints in Sudanese population in plain x-ray and to accounts for the gender differences and artificial knee joint size estimation.

Specific Objectives:

- To measure the normal knee joint surface using the linear normal methods
- To find the difference between the male and female in respect to knee height, circumference and bone measurement.
- To correlate joint surface measurement with age, gender, weight and body mass index (BMI) in normal Sudanese population.
- To find the significant differences between the normal symptomatic patient and the symptomatic patient with bone changes and the associated factors.
- To find a linear model "multiple regression between the knee measurement for normal and abnormal" to estimate the knee joint changes i.e. if exist or not.

- To find correlation between the knee joint measurement and the artificial knee size and hence predicting the artificial knee size before surgery.

1.6. Over view of the study

To make the aims of the study stated above true, the thesis falls into five chapters: Chapter one, which is an introduction, deals with theoretical frame work of the study. It presents the statement of the of the study problems, objectives of the study and important of the study. Chapter two, deals with theoretical background of knee joint (anatomy, physiology and pathology), review of the instrumentations and techniques which include knee joint imaging, measuring and literature review (previous studies). While chapter three discusses the material and method and chapter four include presentation of the results and finally Chapter five deals with the discussion, conclusions of the study and recommendations performed as well as future work.

Chapter Two

- Literature Review
- Previous Studies

Chapter Two

Literature Review

2.1. Anatomy of the knee joint:-

Our knee is the most complicated and largest joint in our body. It's also the most vulnerable because it bears enormous weight and pressure loads while providing flexible movement. When we walk, our knees support 1.5 times our body weight; climbing stairs is about 3-4 times our body weight and squatting about 8 times (Cindy et al, 2014).

The knee joint connects the femur, our thigh bone and longest bone in the body, to the tibia, the second longest bone. There are two joints in the knee, the tibiofemoral joint, which joins the tibia to the femur and the patellofemoral joint which joins the kneecap to the femur. These two joints work together to form a modified hinge joint that not allows the knee to bend and straighten, but also to rotate slightly and from side to side. The knee is part of a chain that includes the pelvis, hip, and upper leg above, and the lower leg, ankle and foot below. All of these work together and depend on each other for function and movement. The knee joint bears most of the weight of the body. When we're sitting, the tibia and femur barely touch; standing they lock together to form a stable unit. Let's look at a normal knee joint to understand how the parts (anatomy) work together (function) and how knee problems can occur (Cindy et al, 2014).

Anatomical terms allow us to describe the body clearly and precisely using planes, areas and lines. Instead of your doctor saying "his knee hurts" she can say "his knee hurts in the anterolateral region" and another doctor will know exactly what is meant.

Some anatomic terms surgeons use as these terms apply to the knee: -

•**Anterior**—facing the knee, this is the front of the knee.

• **Posterior** — facing the knee, this is the back of the knee, also used to describe the back of the kneecap, that is the side of the kneecap that is next to the femur.

• **Medial** — the side of the knee that is closest to the other knee, if you put your knees together, the media side of each knee would touch.

• **Lateral** — the side of the knee that is farthest from the other knee (opposite of the medial side).

Structures often have their anatomical reference as part of their name, such as the medial meniscus or anterior cruciate ligament (Cindy et al, 2014).

The main parts of the knee joint are bones, ligaments, tendons, cartilages and a joint capsule, all of which are made of collagen. Collagen is a fibrous tissue present throughout our body. As we age, collagen breaks down. The adult skeleton is mainly made of bone and a little cartilage in places. Bone and cartilage are both connective tissues, with specialized cells called chondrocyte embedded in a gel-like matrix of collagen and elastin fibers. Cartilage can be hyaline, fibrocartilage and elastic and differ based on the proportions of collagen and elastin. Cartilage is a stiff but flexible tissue that is good with weight bearing which is why it is found in our joints. Cartilage has almost no blood vessels and is very bad at repairing itself. Bone is full of blood vessels and is very good at self repair. It is the high water content that makes cartilage flexible (Cindy et al, 2014).

2.1.1. Bones of the Knee

The bones give strength, stability and flexibility in the knee. Four bones make up the knee, see figure (2.1.).

Tibia —commonly called the shin bone, runs from the knee to the ankle. The top of the tibia is made of two plateaus and a knuckle-like protuberance called the tibial tubercle. Attached to the top of the tibia on each side of the tibial plateau are two crescent-shaped shock-absorbing cartilages called menisci which help stabilize the knee.

• **Patella**—the kneecap is a flat, triangular bone; the patella moves when the leg moves. Its function is to relieve friction between the bones and muscles when the knee is bent or straightened and to protect the knee joint. The kneecap glides along the bottom front surface of the femur between two protuberances called femoral condyles. These condyles form a groove called the patellofemoral groove.

• **Femur**—commonly called the thigh bone; it's the largest, longest and strongest bone in the body. The round knobs at the end of the bone are called condyles.

• **Fibula**—long, thin bone in the lower leg on the lateral side, and runs alongside the tibia from the knee to the ankle (Cindy et al, 2014).

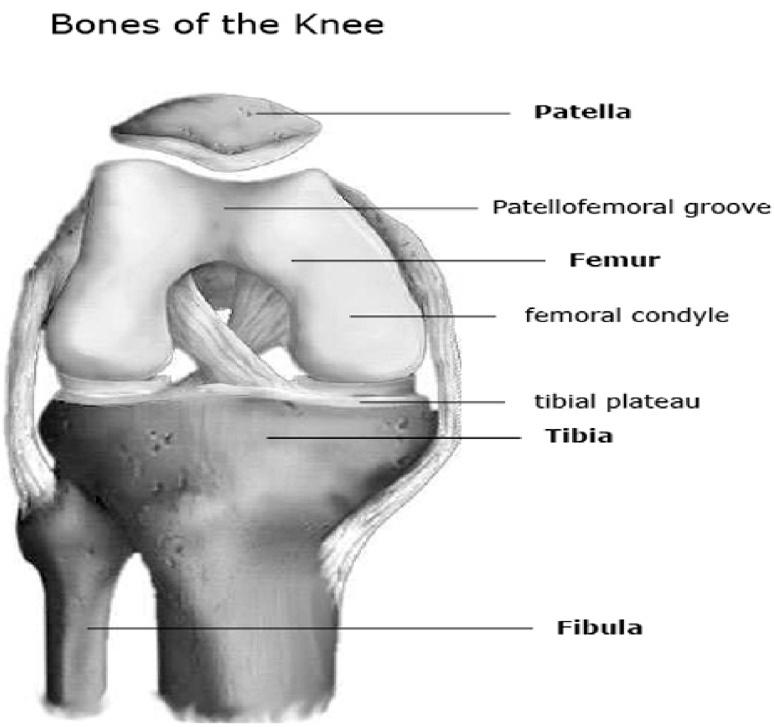


Figure (2.1.) Bones of the knee

2.1.2. Tendons in the Knee

Tendons are elastic tissues that technically part of the muscle and connect muscles to bones. Many of the tendons serve to stabilize the knee. There are two major tendons in the knee—the quadriceps and patellar. The **quadriceps tendon** connects the quadriceps muscles of the thigh to the kneecap and provides the power for straightening the knee. It also helps hold the patella in the patellofemoral groove in the femur. The patellar tendon connects the kneecap to the shinbone (tibia)—which means it’s really a ligament (Cindy et al, 2014).

2.1.3. Ligaments in the knee:

The knee works similarly to a rounded surface sitting atop a flat surface. The function of ligaments is to attach bones to bones and give strength and stability to the knee as the knee has very little stability. Ligaments are strong, tough bands that are not particularly flexible. Once stretched, they tend to stay stretched and if stretched too far, they snap.

• **Medial Collateral Ligament** (tibial collateral ligament) – attaches the medial side of the femur to the medial side of the tibia and limits sideways motion of your knee.

• **Lateral Collateral Ligament** (fibular collateral ligament) – attaches the lateral side of the femur to the lateral side of the fibula and limits sideways motion of your knee.

• **Anterior cruciate ligament** – attaches the tibia and the femur in the center of your knee; it's located deep inside the knee and in front of the posterior cruciate ligament. It limits rotation and forward motion of the tibia.

• **Posterior cruciate ligament** – is the strongest ligament and attaches the tibia and the femur; it's also deep inside the knee behind the anterior cruciate ligament. It limits the backwards motion of the knee.

• **Patellar ligament** – attaches the kneecap to the tibia.

The pair of collateral ligaments keeps the knee from moving too far side-to-side. The cruciate ligaments crisscross each other in the center of the knee. They allow the tibia to "swing" back and forth under the femur without the tibia sliding too far forward or backward under the femur. Working together, the 4 ligaments are the most important in structures in controlling stability of the knee. There is also a patellar ligament that attaches the kneecap to the tibia and aids in stability. A belt of fascia called the iliotibial band runs along the outside of the leg from the hip down to the knee and helps limit the lateral movement of the Figure (2.2.)

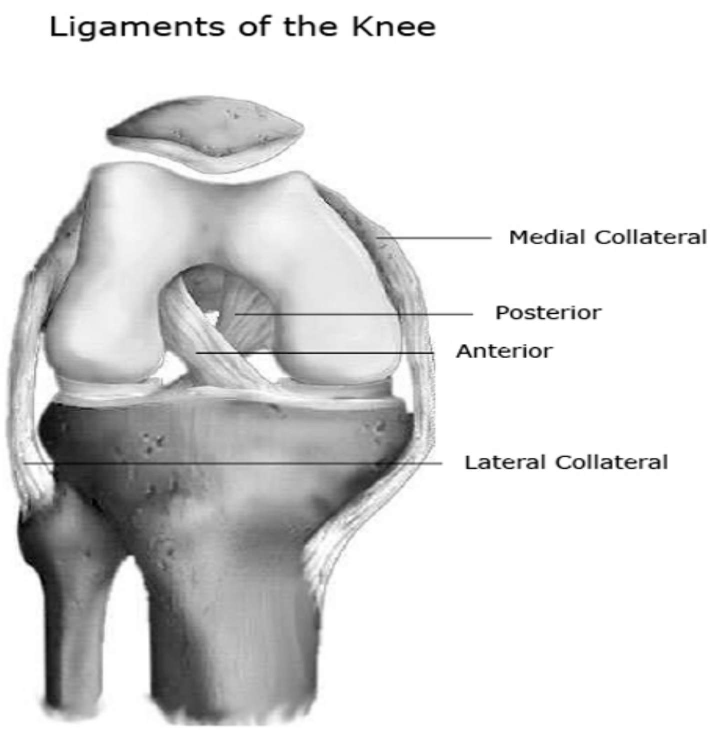


Figure (2.2.) Ligaments of the knee

2.1.4. Nerves of the knee

The two plexi that contribute to the innervations of the lower limbs are the lumber plexus and sacral plexus. The lumber plexus, L1-5 gives rise to the femoral and obturator nerves that innervate the hip flexors and adductors and the knee extensors. The sacral plexus, L4-S4 forms the sciatic nerve which will divides into the common peroneal and tibial nerves at the popliteal fossa (David et al, 2015).

Knee nerves are present which allow the sensory orientation in the joints. These nerves help in coordinating movements while walking, running, standing, etc. These nerves are very delicate and can be affected in case of injury which may lead to severe knee pain.

2.1.5. Cartilage of the knee

The ends of bones that touch other bones—a joint—are covered with articular cartilage. Its gets its name "articular" because when bones move against each other they are said to "articulate." Articular cartilage is a white, smooth, fibrous connective tissue that covers the ends of bones and protects the bones as the joint moves. It also allows the bones to move more freely against each other. The articular cartilages of the knee cover the ends of the femur, the top of the tibia and the back of the patella. In the middle of the knee are menisci—disc shaped cushions that act as shock absorbers. See Figure (2.3.)

• **Medial meniscus** is made of fibrous, crescent shaped cartilage and attached to the tibia.

• **Lateral meniscus** is made of fibrous, crescent shaped cartilage and attached to the tibia.

• **Articular cartilage** is on the ends of all bones in any joint, in the knee joint it covers the ends of the femur and tibia and the back of the patella. The articular cartilage is kept slippery by synovial fluid (which looks like egg white) made by the synovial membrane (joint lining). Since the cartilage is smooth and slippery, the bones move against each other easily and without pain (Cindy et al, 2014).

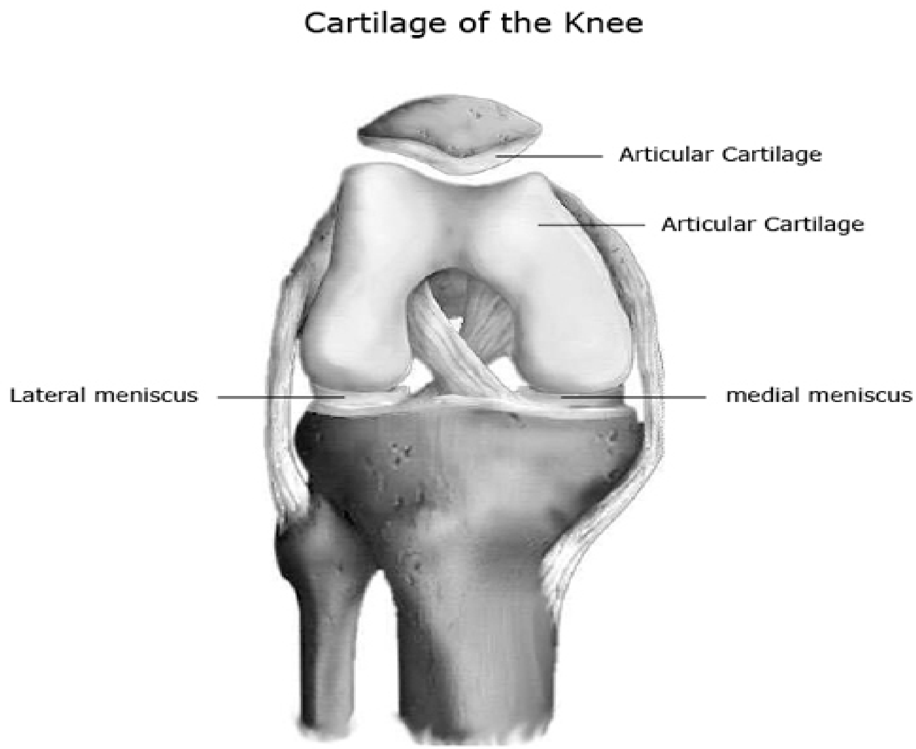


Figure (2.3) Cartilages of knee

In a healthy knee, the rubbery meniscus cartilage absorbs shock and the side forces placed on the knee. Together, the menisci sit on top of the tibia and help spread the weight bearing force over a larger area. Because the menisci are shaped like a shallow socket to accommodate the end of the femur, they help the ligaments in making the knee stable. Because the menisci help spread out the weight bearing across the joint, they keep the articular cartilage from wearing away at friction points.

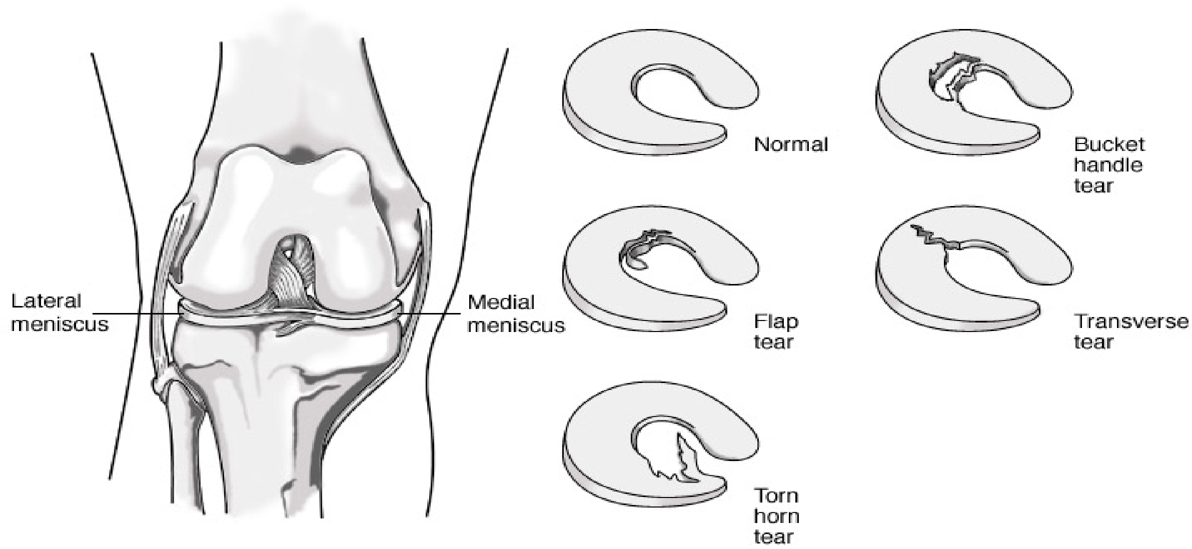


Figure (2.4.) Diagram of normal meniscus and its tears.

The weight bearing bones in our body are usually protected with articular cartilage, which is a thin, tough, flexible, slippery surface which is lubricated by synovial fluid. The synovial fluid is both viscous and sticky lubricant. Synovial fluid and articular cartilage are a very slippery combination—3 times more slippery than skating on ice, 4 to 10 times more slippery than a metal or plastic knee replacement. Synovial fluid is what allows us to flex our joints under great pressure without wear (Cindy et al, 2014).

2.1.6. Muscles

The muscles in the leg keep the knee stable, well aligned and moving—the quadriceps (thigh) and hamstrings. There are two main muscle groups—the quadriceps and hamstrings. The quadriceps are a collection of 4 muscles on the front of the thigh and are responsible for straightening the knee by bringing a bent knee to a straight position. The hamstrings is a group of 3 muscles on the back of the thigh and control the knee moving from a straight position to a bent position, see figures (2.5.) and (2.6.) (Cindy et al, 2014).

Figure (2.5.) A coronal section of the knee joint shows its muscles.

Figure (2.6.) A sagittal section of the knee joint shows its muscles.

2.1.7. The Joint Capsule

The capsule is a thick, fibrous structure that wraps around the knee joint. Inside the capsule is the synovial membrane which is line by the synovium, a soft tissue that secretes synovial fluid when it gets inflamed and provides lubrication for the knee.

Bursae There are up to thirteen bursa of various sizes around the knee. These fluid filled sacs cushion the joint and reduce friction between muscles, bones, tendons and ligaments. The prepatellar bursa is one of the most significant bursa and is located on the front of the knee.

Plicae are folds in the synovium. Plicae rarely cause problems but sometimes they can get caught between the femur and kneecap and cause pain (Cindy et al, 2014).

2.1.8 Knee Arteries and Veins

The main arteries supplying the knee region are femoral, popliteal, anterior tibial and posterior tibial arteries. Although the popliteal artery is deep in the popliteal fossa, the popliteal pulse can still be felt but the knee has to be bent and the person still has to press deep into the fossa.

There are the deep veins are the same as the names of the artery they accompany. There are two important superficial veins: the great and lesser saphenous veins. The great saphenous is often used in coronary bypass operations as it has thicker walls than most veins and therefore it can substitute for an artery. Removal of this vein does not cause a problem as there are still the deep veins to return the blood to the heart (David et al, 2015).

2.2. Physiology of the Knee:-

So now we have all the parts, let's see how the knee moves (articulates)—which is how we walk, stoop, jump, etc. The knee has limited movement and is designed to move like a hinge.

The **Quadriceps Mechanism** is made up of the patella (kneecap), patellar tendon, and the quadriceps muscles (thigh) on the front of the upper leg. The patella fits into the patellofemoral groove on the front of the femur and acts like a fulcrum to give the leg its power. The patella slides up and down the groove as the knee bends. When the quadriceps muscles contract they cause the knee to straighten. When they relax, the knee bends. In addition the hamstring and calf muscles help flex and support the knee (Cindy et al, 2014).

2.3. Pathology of the Knee:-

The knee doesn't have much protection from trauma or stress (pressure or force).

2.3.1. Symptoms

Knee symptoms come in many varieties. Pain can be dull, sharp, constant or off-and-on. Pain can also be mild to agonizing. The range of motion in the knee can be too much or too little. You may hear grinding or popping, the muscles may feel weak or the knee can lock. Some knee problems only need rest and ice; others need physical therapy or even surgery.

• **Swelling.** One of the most common symptoms is local swelling. There are two types of swelling. One is caused by the knee producing too much synovial fluid and the other is caused by bleeding into the joint (hemarthrosis). Swelling within the first hour of an injury is usually from bleeding. Swelling from 2-24 hours is more likely to be from the joint producing large amounts of synovial fluid trying to lubricate an abnormality inside the knee. The best home treatment for swelling is R.I.C.E. therapy. Chronic swelling can distend the knee, prohibit full range of motion and the muscles can atrophy from non-use. Also, if the cause of the swelling is blood, the blood can be destructive to the joint.

• **Locking**. Locking is when something is keeping the knee from fully straightening out. This is usually a loose body in the knee. The loose body can be as small as a grain of sand or as big as a quarter. The best treatment is removal of the loose body by arthroscopy. Another type of locking is when the knee hurts so bad that you just won’t use it. The best treatment here is rest and maybe some ice; swelling is not usually present.

• **Giving Way.** If your kneecap slips out of is groove for an instant, it causes your thigh muscles to lose control causing the feeling of instability—that is, you don’t feel like your knee is stable, won’t support your weight—and you usually try to grab hold of something for support. Giving way can also be caused by weak leg muscles or an old ligament injury.

• **Snaps, Crackles and Pops.** Noises coming from your knee without pain are likely nothing to worry about. Sometimes the noise is caused by loose bodies that just float around and are not causing pain or injury to the knee. However, if you have pain, swelling or loss of knee function, you should see an orthopedist. The most common cause—Chondromalacia patella—is caused by an injury. Another common cause is a dislocating kneecap—that is, a kneecap that keeps slipping out of its groove. Pops without trauma (injury) are not worrisome; pops with trauma can mean ligament tears. Crackling, grinding or grating (crepitus) means there is a roughness to the bone surfaces and likely from degenerative disease or wear-and-tear arthritis (osteoarthritis).

• **Pain and Tenderness.** Where and how bad the pain is will help find the underlying cause. It also helps to know what caused it and what makes it hurt. Pain that gets worse with activity is often tendinitis or stress fractures. Pain and tenderness accompanied by swelling can be more serious such as a tear or sprain. Some pain can be caused by muscles spasms associated with trauma (Cindy et al, 2014).

2.3.2. Pathological Conditions and Syndromes

- Osteochondritis Dissecans
- Osteoarthritis (Degenerative Arthritis) and Infectious Arthritis
- Chondromalacia Patellae
- Gout
- Plica Syndrome
- Rheumatoid Arthritis
- Chondromalacia

2.3.3. Traumatic Knee Injuries

- Anterior cruciate ligament (ACL) Injury
- Meniscus tear
- Lateral and Medial Collateral Ligament Injury
- Posterior Cruciate Ligament (PCL) Injury

- Patellar Injuries and Rupture of the Patellar Tendon
- Dislocation of the Patella
- Fracture and Stress Fracture

2.3.4. Repetitive Knee Injuries

- Patellofemoral Syndrome (Runner's Knee)
- Tendonitis
- Bursitis (Housemaid's Knee)
- Iliotibial Band Syndrome
- Osgood-Schlatter Disease

2.4. Knee Surgeries:

Several orthopedic surgical procedures that are available to correct joint dysfunction are:

1. Arthroplasty a joint is given movement by either reshaping the bones of the joint, or a soft tissue or metal disc is placed between the reshaped ends; or the joint or part of the joint is replaced by a plastic or metal prosthesis
2. Tendon Lengthening to extend the tendon without losing its function
3. Osteotomy bone is cut for bone repair or joint repair
4. Arthrodesis a fusion at the joint surface. Needed when support cannot de maintained
5. Arthroscopy a small incision is made where an instrument, arthroscopy, is inserted; to explore and also used to remove injured/diseased materials if necessary

6. Rehabilitation it is the attempt to restore normal (as much as possible) function to the joint. Prerequisites for successful rehabilitation of the knee include an appropriately motivated, cooperative patient and an appropriately designed physical therapy program. One wants to stay away from reinjured, so programs must be individualized in accordance with the injury type the therapist is dealing with (Berquist, 2006).

2.5. Methods of imaging Knee joint:-

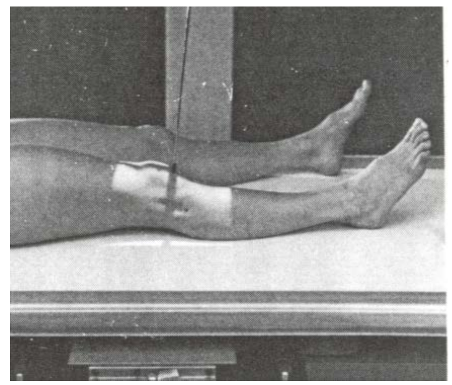
2.5.1. Plain x-ray:-

Basic Projections: - AP, Lateral, Oblique, Tunnel and skyline view

1- AP Knee Joint

Exposure Factors

Kv.	mAs	FFD (cm)	Grid	Focus	Cassette
65	5	100	Yes	Fine	18x24 cm



Patient Position: Supine with leg extended

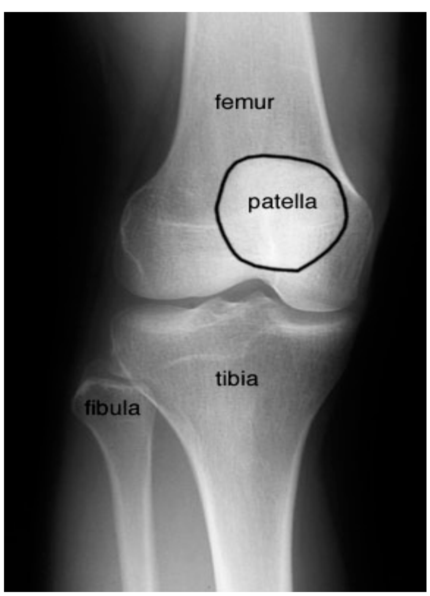
Part position:

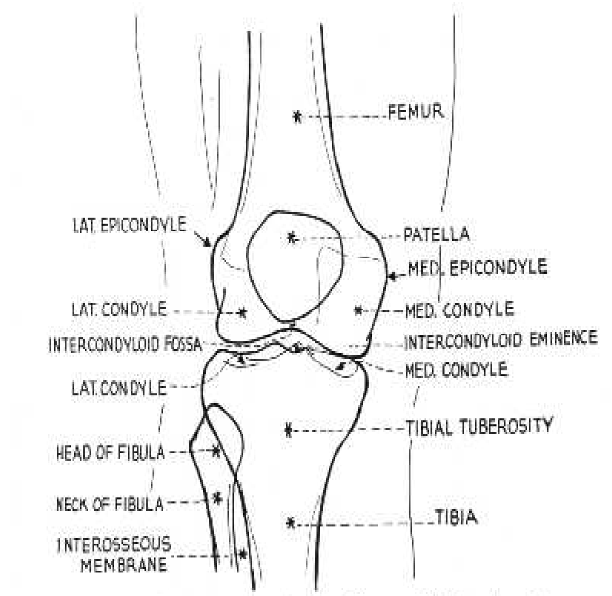
- Adjust knee to cassette
- Slightly rotate leg medially to centralize patella

Central Ray: 5-7 degrees cephalic

Center Point: ½ inch inferior to patellar apex

Structure shown: Femorotibial joint, distal femur and proximal tibia & fibula





2- Lateral knee joint: Mediolateral or lateromedial

Exposure Factors:

Kv	mAs	FFD (cm)	Grid	Focus	Cassette
63	5	100	Yes	Fine	18x24cm

Patient Position: Semi prone turn onto affected side

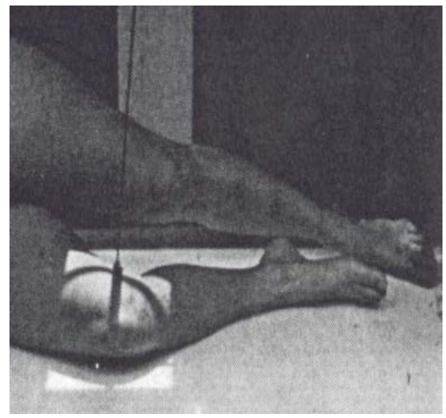
- Knee flexed 20-30 degrees

Part position: Center knee by placing cassette

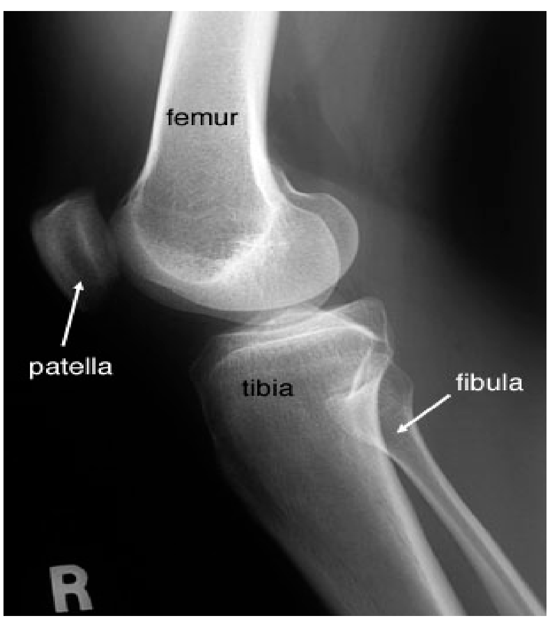
1 inch distal to medial condoyle

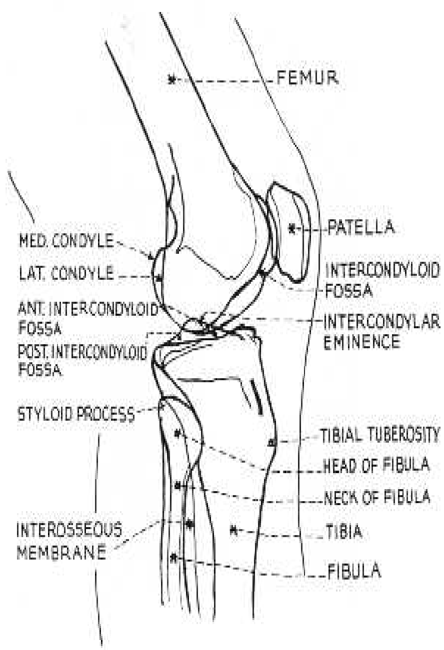
Central Ray: 5degrees cephalic

Center Point: 1 inch inferior to medial condoyle



Structure shown: Lateral view of distal femur and proximal tibia, patella



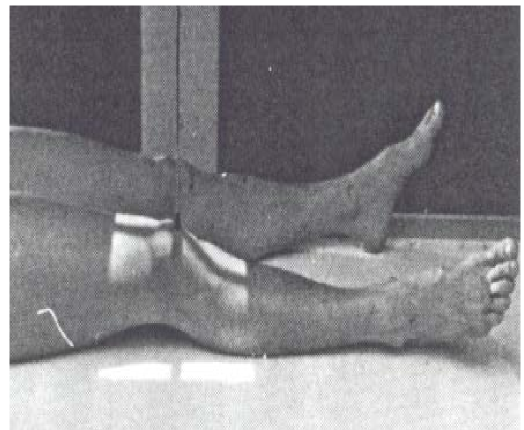


3- AP Oblique knee joint (Lateral or external rotation)

Exposure Factors

Kv	mAs	FFD (cm)	Grid	Focus	Cassette
65	5	100	Yes	Fine	24 x 30 cm

Patient Position: Supine, extend affected knee



Part position:

Adjust knee to cassette

Rotate affected knee with entire leg 45

Degrees laterally

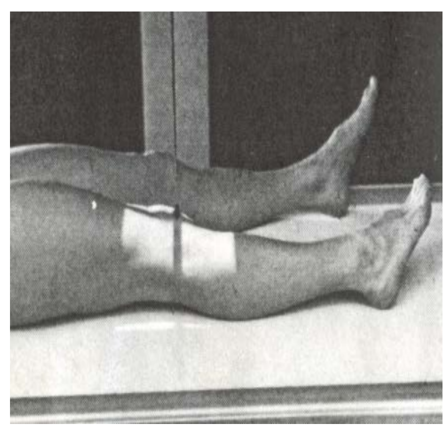
Central Ray: Perpendicular

Center Point: at level of patella apex

Structure shown: Oblique view of distal femur and proximal tibia and fibula, patella.

4- Medial Oblique knee joint:- Exposure Factors (as above)

Patient Position: Supine, extend affected knee



Part position: Adjust knee to cassette

Rotate affected knee with entire leg

45 degrees medially

Central Ray: Perpendicular

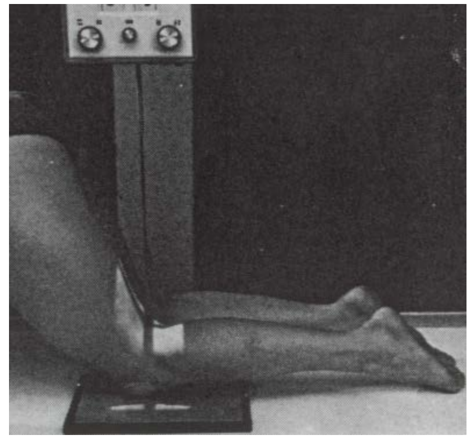
Center Point: At level of patella apex

Structure shown: oblique view of distal femur and proximal tibia and fibula, patella.

5- Knee joint (Tunnel view for intercondylar fossa):

Exposure Factors

Kv	mAs	FFD (cm)	Grid	Focus	Cassette
65	5	100	Yes	Fine	24 x 30 cm



Patient Position: Kneeling on radiographic table, side elevated, Affected knee flexed 70^0

Part position: Adjust knee to cassette

Patellar apex centered to cassette

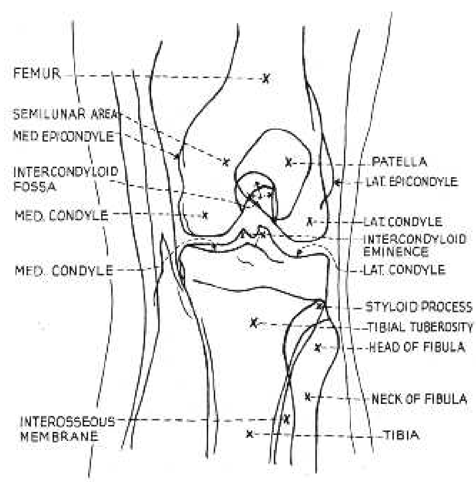
Place and support under ankle and leg of unaffected side

Ask patient to slowly lean forward 20-25 Degrees

Central Ray: Perpendicular to lower leg

Center Point: Long axis of leg entering mid popliteal crease

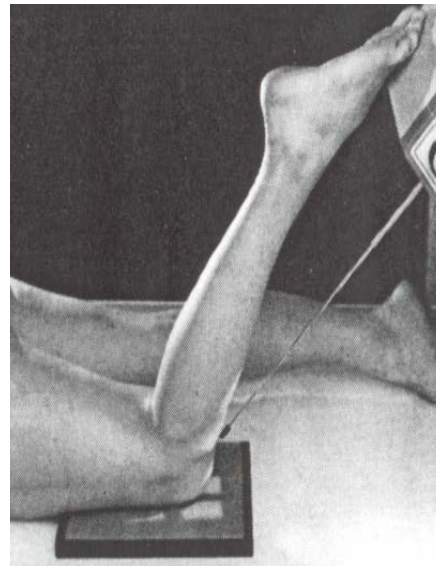
Structure shown: Intercondylar fossa without superimposition with patella (Kenneth Bontrager, 2001).



6- (Tangential View) (Axial or skyline):

Exposure Factors

Kv	mAs	FFD (cm)	Grid	Focus	Cassette
65	5	100	No	Fine	24 x 30 cm



Patient Position:

Prone with foot resting on table

Part position: Flex affected knee, Tibia & Fibula must form $(50\text{-}60)^0$ angles from table

Central Ray: 45 degrees cephalic

Center Point: through patellofemoral joint

Structure shown:

Patella &intercondylar sulcus (Trochlear groove)

(Kenneth Bontrager, 2001).

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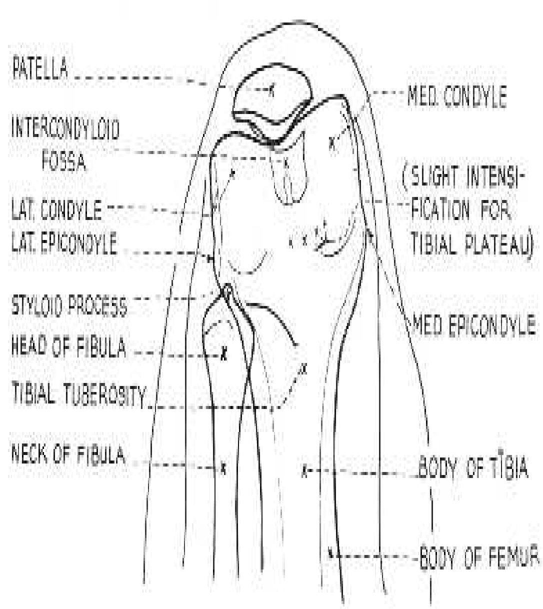


2.5.2. Magnetic Resonance Imaging (MRI):

MRI of the knee provides detailed images of structures within the knee joint, including bones, cartilage, tendons, ligaments, muscles and blood vessels, from many angles. Magnetic resonance imaging (MRI) is a noninvasive medical test that helps physicians diagnose and treat medical conditions.

MRI uses a powerful magnetic field, radio frequency pulses and a computer to produce detailed pictures of organs, soft tissues, bone and virtually all other internal body structures. MRI does not use ionizing radiation (x-rays).

Detailed MR images allow physicians to evaluate various parts of the body and determine the presence of certain diseases. The images can then be examined on a computer monitor, transmitted electronically, printed or copied to a CD.

2.5.3. Computed Tomography (CT scan):

Computed tomography and magnetic resonance imaging give much more detail than conventional x-rays and may be done to determine the extent and exact location of damage. These tests can also be used to detect fractures that are not visible on x-rays (such as some small fractures of the hip and pelvis). MRI is especially valuable for imaging muscles, ligaments and tendons. MRI can be used if the cause of pain is thought to be a severe soft-tissue problem (for example, rupture of a major ligament or tendon or damage to important structures inside the knee joint). CT is useful if MRI is not recommended or unavailable. CT exposes people to ionizing radiation. CT best images bone. However, sometimes MRI is better than CT for imaging bone. The amount of time a person spends undergoing CT is much less than for MRI. MRI is more expensive than CT and with the exception of when the open-sided units are used, many people feel claustrophobic inside the MRI unit.

2.5.4. Ultrasonography

Ultrasonography is being used more and more frequently to identify inflammation in and around joints and tears or inflammation of tendons. Ultrasonography is also used as a guide when a needle needs to be put into a joint (for example, to inject drugs or to remove joint fluid). As an alternative to CT and MRI, ultrasonography is less expensive and, unlike CT, involves no exposure to radiation. However, ultrasonography is not always available and requires that the people doing and interpreting the scan be very skilled.

2.5.5. Bone Scanning

Bone scanning is an imaging procedure that is occasionally used to diagnose a fracture, particularly if other tests, such as plain x-rays and CT or MRI, do not reveal the fracture. Bone scanning involves use of a radioactive substance (technetium-99m–labeled pyrophosphate) that is absorbed by any healing bone. The procedure can also be used when a bone infection or a tumor that has spread from a cancer elsewhere in the body is suspected. Although a bone scan may show a problem in the bone, it may not show whether the problem is a fracture, tumor, or infection. The radioactive substance is given by vein (intravenously) and is detected by a bone-scanning device, which creates an image of the bone that can be viewed on a computer screen.

2.5.6. Joint Aspiration

Joint aspiration (arthrocentesis) is used to diagnose certain joint problems. For example, it is the most direct and accurate way to determine whether joint pain and swelling is caused by an infection or crystal-related arthritis (such as gout). For this procedure, a doctor first injects an anesthetic to numb the area. Then the doctor inserts a larger needle into the joint space, draws out (aspirates) joint fluid (synovial fluid), and examines the fluid under a microscope. A doctor removes as much fluid as possible and notes its color and clarity. Other tests, such as white blood cell count and culture, are done on the fluid. The doctor can often make a diagnosis after analyzing the fluid. For example, a sample of fluid may contain bacteria, which confirm a diagnosis of infection. Or, it may contain certain crystals. For example, finding uric acid crystals confirms a diagnosis of gout, and calcium pyrophosphate dehydrate crystals confirm a diagnosis of pseudo gout. Usually done in the doctor's office or an emergency department, this procedure is typically quick, easy, and relatively painless. The risk of joint infection is minimal.

2.5.7. Arthroscopy

Arthrography is an x-ray procedure in which a radiopaque dye is injected into a joint space to outline the structures, such as ligaments inside the joint. Arthrography can be used to view torn ligaments and fragmented cartilage in the joint. However, MRI is now generally used in preference to arthrography.

Arthroscopy is a procedure in which a small (diameter of a pencil) fiberoptic scope is inserted into a joint space, allowing the doctor to look inside the joint and to project the image onto a video monitor. The skin incision is very small. This procedure is done in a hospital or surgical center. The person is given local, spinal, or general anesthesia or a combination. During arthroscopy, doctors can take a piece of tissue (such as joint cartilage or the joint capsule) for analysis (biopsy), and, if necessary, do surgery to correct the condition. Disorders commonly found during arthroscopy include inflammation of the synovium lining the joint (synovitis); ligament, tendon, or cartilage tears; and loose pieces of bone or cartilage. Such conditions affect people with arthritis or previous joint injuries as well as athletes. All of these conditions can be repaired or removed during arthroscopy. There is a very small risk of joint infection with this procedure. See Figure (2.7.)

Recovery time after arthroscopic surgery is much faster than after traditional surgery. Most people do not need to stay overnight in the hospital. (Merck, 2010)

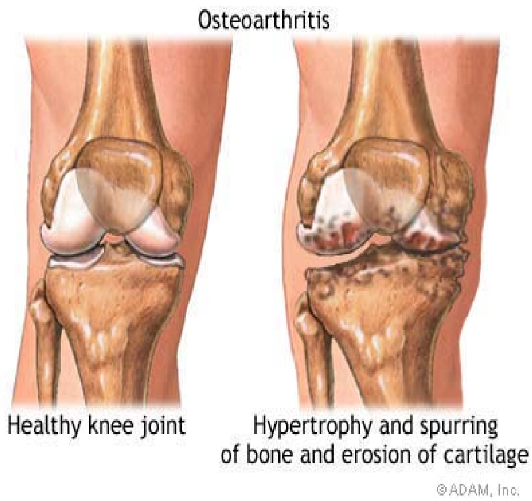
Figure (2.7.) Arthroscopic Surgery

2.6. Knee joint replacement:

Joint replacement procedures have improved dramatically during the past 30 years fueled by the changes in techniques for hips and knees. Joint replacements in other anatomic regions also have become more popular. It is essential to understand the importance of pre- and postoperative imaging for evaluating patients. Preoperative images are used in concert with clinical data to select the appropriate patients and components. Postoperative imaging is critical for evaluating position and potential complications. Appropriate selection of imaging modalities is essential to provide optimal, cost-effective patient care. (Media Partners, 2010).

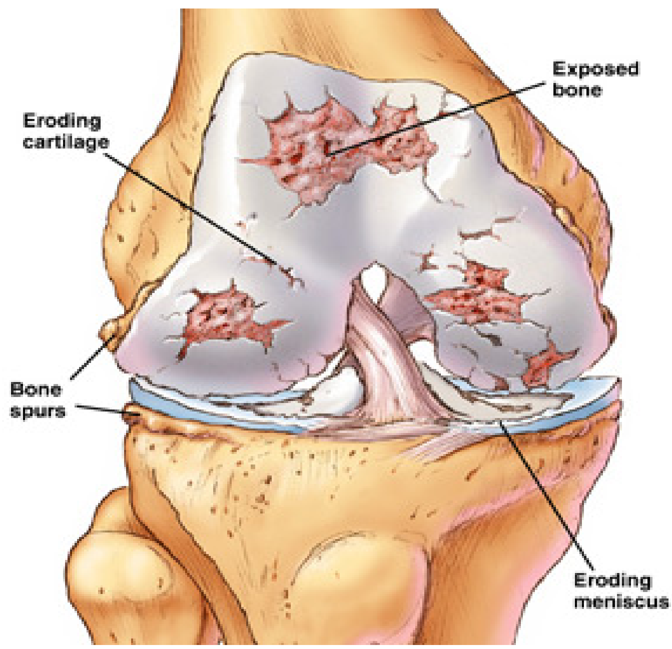
Your surgeon explained the results of the exam, x-rays and diagnostic tests. He told the patient why surgery is recommended, and explained the surgical procedure and the expected outcome you. The risks of having or not having the surgery, the benefits of having the surgery, and the options available to patient instead of surgery will be explained. The more the patient knows, the more confident he will be about doing his part in his treatment and recovery.

The surgeon asks at the patient to sign a surgical consent form. This form is a legal paper that says the surgeon has told the patient about surgery and any risks you might be taking by having the surgery. By signing this form, the patient saying that he *understands* the risks and agrees to have the surgery. Ask the surgeon about any concerns he has *before* sign this form (Media Partners, 2010).



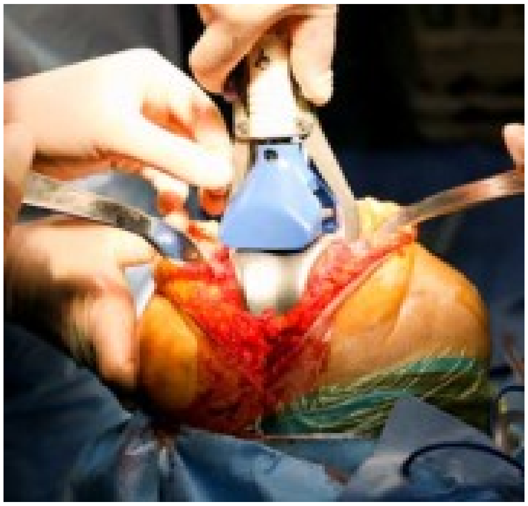
A.

B.



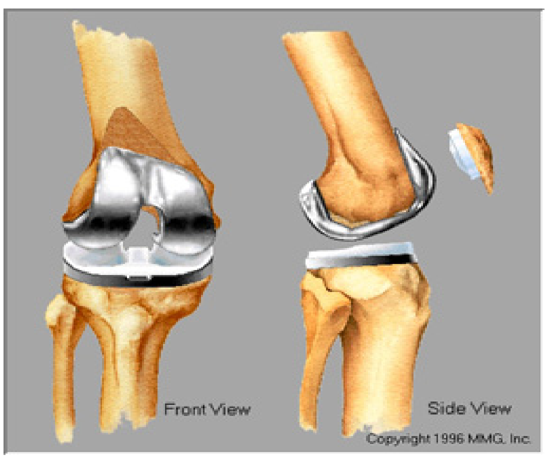
C.

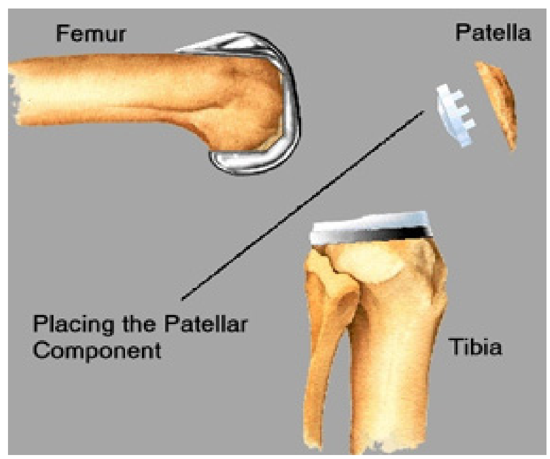
Figure (2.8.) A, B and C Shows the causes of knee replacement



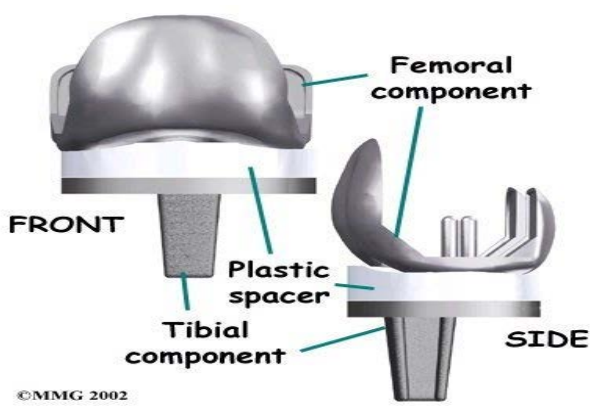
A. Knee surgery B. Knee replacement incision closed with staples

Figure (2.9.) A and B. Images shows knee replacement surgery



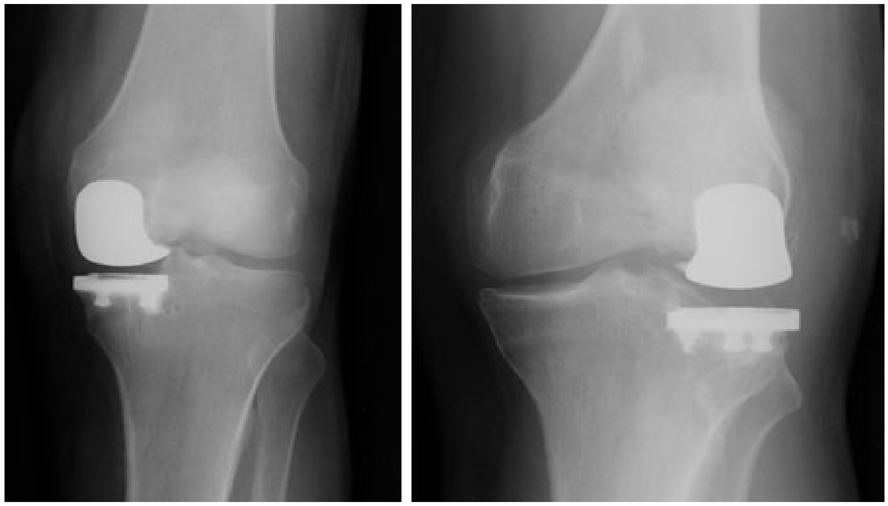


A. B.



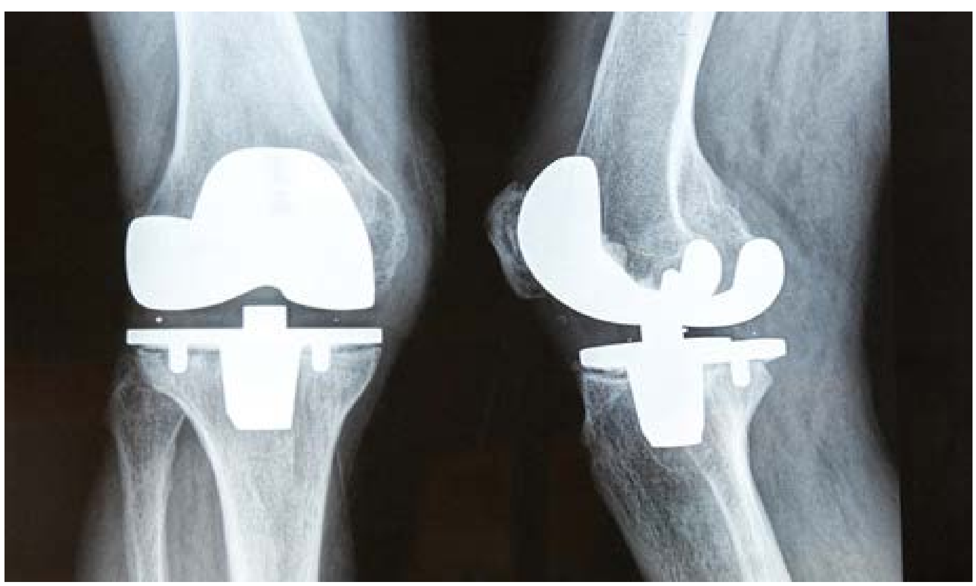
C.

Figure (2.10.) A, B and C. Images shows knee replacement components'



A.

B.



C.

Figure (2.11.) A, B and c. X-rays of different types of artificial knee devices

2.7. Complications of Knee Replacement Surgery:

As with all major surgical procedures, complications can occur. The most common complications following knee replacement are: Thrombophlebitis, Infection in the joint, Stiffness of the joint and Loosening of the joint. This is not intended to be a complete list of the possible complications, but these are the most common.

Thrombophlebitis, sometimes called Deep Venous Thrombosis (DVT), can occur after any operation. It is more likely to occur following surgery on the hip, pelvis, or knee. DVT occurs when the blood in the large veins of the leg forms blood clots within the veins. This may cause the leg to swell and become warm to the touch and painful. If the blood clots in the veins break apart they can travel to the lung. Once in the lung they get lodged in the capillaries of the lung and cut off the blood supply to a portion of the lung. This is called a pulmonary embolism. Pulmonary means "lung". An embolism is a fragment of something traveling through the vascular system. Most surgeons take preventing DVT very seriously. There are many ways to reduce the risk of DVT, but probably the most effective is getting you moving around as soon as possible! Some of the commonly used preventive measures include: Pressure stockings to keep the blood in the legs moving and Medications that thin the blood and prevent blood clots from forming.

Infection, Infection can be a very serious complication following an artificial joint. The chance of getting an infection following total hip replacement is probably around 1 in 100 total hip replacements. Some infections may show up very early – before you leave the hospital. Others may not show up for months, or even years, after the operation. Also, an infection can spread into the artificial joint from other infected areas. Your surgeon may want to make sure that you take antibiotics when you have dental work, or surgical procedures on your bladder or colon to reduce the risk of spreading germs to your new joint.

Stiffness, In some cases, the ability to bend the knee does not return to normal after an artificial knee replacement. Many orthopedic surgeons are now using a machine known as a CPM machine (Constant Passive Motion) immediately after surgery to try and increase the range of motion following artificial knee replacement. Other orthopedic surgeons rely on physical therapy beginning immediately after the surgery to regain the motion. It is not clear which is the best approach. Both approaches have benefits and risks, and the choice is usually made by the surgeon based on his experience and preferences. To be able to use the leg effectively to rise from a chair, the knee must bend at least to 90 degrees. A desirable range of motion should be greater than 110 degrees. Balancing of the ligaments and soft tissues (during surgery) is the most important determining factor in regaining an adequate range of motion following knee replacement, but sometimes increasing scarring after surgery can lead to an increasingly stiff knee. If this occurs, your surgeon may recommend taking you back to the operating room, placing you under anesthesia once again, and forcefully manipulating the knee to regain motion. Basically, this allows the surgeon to breakup and stretch the scar tissue without you feeling it. The goal is to increase the motion in the knee without injuring the joint

Loosening, The major reason that artificial joints eventually fail continues to be loosening of the joint where the metal or cement meets the bone. There have been great advances in extending the life of an artificial joint. Still, most joints will eventually loosen and require a revision. Hopefully, you can expect 12-15 years of service from your artificial knee. In some cases the knee will loosen earlier than that. Just like your diseased knee, a loose joint cause’s pain. Once the pain becomes unbearable, another operation will probably be required to replace the knee (Media Partners, 2010).

2.8. Previous studies:

Andrew et al, (2011) said that it has been suggested that knee height is a determinant of knee joint load. Nonetheless, no study has directly examined the relationship between anthropometric measures of height and knee joint structures, such as cartilage. 89 asymptomatic community-based adults aged 25-62 with no diagnosed history of knee arthropathy were recruited. Anthropometric data (knee height and body height) were obtained by standard protocol, while tibial cartilage volume and defects, as well as bone area were determined from magnetic resonance imaging. Static knee alignment was measured from the joint radiograph. All anthropometric height measures were associated with increasing compartmental tibial bone area ($p \leq 0.05$). Although knee height was associated with tibial cartilage volume (e.g. β = 27 mm3 95% CI 7- 48; $p = 0.009$ for the medial compartment), these relationship no longer remained significant when knee height as a percentage of body height was analyses. Knee height as a percentage of body height was associated with a reduced risk of medial tibial cartilage defects (odds ratio 0.6; 95% confidence interval 0.4 - 1.0; $p = 0.05$).

The association between increased anthropometric height measures and increased tibial bone area may reflect inherently larger bony structures. However the beneficial associations demonstrated with cartilage morphology suggest that an increased knee height may confer a beneficial biomechanical environment to the chondrocyte of asymptomatic adults.

Nicholas et al, (1976) said that the circumference of the knees and thighs at three locations were measured in 10 patients on two consecutive occasions by three observers. Analysis of the results for interobserver, intraobserver and among-patient variation established that a change in circumference noted by different observers on two different days is significant if it exceeds 1V5 cm at the midpatella, 2-7 cm at 7 cm above, and 3-5 cm at 15 cm above the patella. If a single observer performs both measurements, the change need exceed only 1'0, 2-0, and 2-7 cm, respectively, to be significant. The objective measurement of joint inflammation is a frequent research study, but often a neglected part of clinical evaluation (Boardman and Hart, 1967). The complicated equipment necessary for joint scanning and infrared photography, and even the measurement of the proximal interphalangeal and distal interphalangeal joints by jewelers' rings (Hart and Clark, 1951) and tape devices (Willkens, Gleichert and Gade, 1973; Webb and others, 1973) undoubtedly discourage the adoption of these techniques for routine clinical evaluation. An ordinary tape measure would satisfy the need for simple, readily available equipment to measure joint circumference, an acknowledged index of joint inflammation. The results of this study indicate that measurement of the knee with an ordinary tape measure provides reproducible results when used by both single and multiple observers.

Hohe et al, (2002) assessed knee joint incongruity using MRI. Their purpose of this study was to develop an MR-based technique for quantitative analysis of joint surface size, surface curvature, and joint incongruity and to assess its reproducibility under in vivo imaging conditions. The surface areas were determined after 3D reconstruction of the joint by triangulation and the incongruity by Gaussian curvature analysis. The precision was tested by analyzing four replicated MRI datasets of human knees in 14 individuals. The algorithms were shown to produce accurate data in geometric test objects. The interscan precision was <4% (CV %) for surface area, 2.9 –5.7 m-1 (SD) for the mean principal curvature, and 4.1–7.4 m-1 for congruence indices. Incongruity was highest in the femoropatellar joint (79.7 m-1) and lowest in the medial femorotibial joint (28.6 m-1). This technique will permit identification of the specific role of surface size, curvature, and incongruity as potential risk factors for osteoarthritis. The computation of the size of the surface areas displayed no difference with the expected value for a plane and a consistent underestimation of 1.4% for cylinders of different radii (10 mm, 20 mm, and 40 mm). For spheres, the differences were 3.2%, 1.6%, and 4.1% for radii of 10 mm, 20 mm, and 40 mm, respectively. The minimal and maximal curvatures were accurately computed for the plane and were consistently underestimated by 0.2% in cylinders of various sizes. In a quarter sphere, the differences were 1%, and in a semi sphere 2%. For the parabolic and the hyperbolic parabolic, the deviations were 0.2%, both for the minimal and maximal principal curvatures.

Mazzuca et al, (2003) states the recent research on the radiographic imaging of knee OA has helped clarify the features of imaging protocols that contribute to accurate representation of disease severity--specifically, the thickness of articular cartilage--and to sensitive detection of disease progression. The absence of standards for reproducible positioning of the knee in the conventional standing AP view obscures the true rate and variability of JSN in knee OA. Moreover, the standing AP view is susceptible to systematic bias insofar as longitudinal changes in knee pain might lead to over- or underestimation of radiographic JSW depending on the direction of change in pain. More recent protocols for standardized knee radiography have been designed to achieve reproducible alignment of the medical tibial plateau and x-ray beam. As a group these protocols permit measurement of tibiofemoral JSW with remarkable precision--the sine qua non of sensitivity to change--however, only limited longitudinal data is available to permit a direct evaluation of the suitability of these protocols for use in clinical DMOAD trials. Longitudinal studies published to date suggest that fluoroscopic positioning methods are superior to nonfluoroscopic methods with respect to reproducing the position of the knee in serial examinations performed several years apart. Fluoroscopic methods also appear to be superior with respect to achieving parallel alignment of the medial tibial plateau and x-ray beam in serial radiographs, a positioning marker strongly associated with sensitive detection of JSN in knee OA. It is important to note that while the various standardization protocols described in this article perform with great success in short-term demonstrations of the reproducibility of positioning and radiographic JSW, differences clearly exist between protocols in the quality of performance over intervals relevant to clinical DMOAD trials. Over intervals of 2 to 3 years, changes in patient characteristics (e.g., severity of knee pain, body weight, load bearing, varus--valgus deformity) and uncontrollable events related to radiography (e.g., technologist turnover, equipment upgrades) have ample opportunity to affect the technical quality of a radiological knee examination. It is difficult, therefore, to conclude whether or not an apparent difference with respect to sensitivity to OA progression between specific radiographic protocols, implemented in separate locations with different cohorts, reflects a robust difference in technical quality or uncontrollable patient variables and events. The most informative recent studies have provided the results of head-to-head longitudinal comparisons of alternative standardization protocols or conventional examination methods performed concurrently in the same subjects [20, 22]. Additional comparative studies of this nature are needed, however, to fully characterize the strengths and weaknesses of currently available alternatives in a way that will permit generalizable conclusions regarding the best radiographic methods for multicenter DMOAD trials.

Karen, et al. (2008) study the clinical use of minimum joint space width (mJSW) and cartilage volume and thickness has been limited to the longitudinal measurement of disease progression (i.e. change over time) rather than the diagnosis of OA in which values are compared to a standard. This is primarily due to lack of establishment of normative values of joint space width and cartilage morphometry as has been done with bone density values in diagnosing osteoporosis. Thus, the purpose of this pilot study is to estimate reference values of medial joint space width and cartilage morphometry in healthy individuals of all ages using standard radiography and peripheral magnetic resonance imaging.

For this cross-sectional study, healthy volunteers underwent a fixed-flexion knee X-ray and a peripheral MR (pMR) scan of the same knee using a 1T machine (ONI OrthOne™, Wilmington, MA). Radiographs were digitized and analyzed for medial mJSW using an automated algorithm. Only knees scoring ≤1 on the Kellgren-Lawrence scale (no radiographic evidence of knee OA) were included in the analyses. All 3D SPGRE fat-sat sagittal pMR scans were analyzed for medial tibial cartilage morphometry using a proprietary software program (Chondrometrics GmbH). Of 119 healthy participants, 73 were female and 47 were male; mean (SD) age 38.2 (13.2) years, mean BMI 25.0 (4.4) kg/m2. Minimum JSW values were calculated for each sex and decade of life. Analyses revealed mJSW did not significantly decrease with increasing decade ($p > 0.05$) in either sex. Females had a mean (SD) medial mJSW of 4.8 (0.7) mm compared to males with corresponding larger value of 5.7 (0.8) mm. Cartilage morphometry results showed similar trends with mean (SD) tibial cartilage volume and thickness in females of 1.50 (0.19) μL/mm2 and 1.45 (0.19) mm, respectively, and 1.77 (0.24) μL/mm2 and 1.71 (0.24) mm, respectively, in males. These data suggest that medial mJSW values do not decrease with aging in healthy individuals but remain fairly constant throughout the lifespan with "healthy" values of 4.8 mm for females and 5.7 mm for males. Similar trends were seen for cartilage morphology. Results suggest there may be no need to differentiate a t-score and a z-score in OA diagnosis because cartilage thickness and JSW remain constant throughout life in the absence of OA.

Alexandra et al, (2008) stated that the gold standard for measuring knee alignment is mechanical axis determined using full-limb radiographs (FLR). Measurement of joint alignment using antero-posterior (AP) knee radiographs is more accessible, economical and involves less radiation exposure to the patient compared with using full-limb radiographs. The aim of this study was to compare and assess the reproducibility of knee joint axial alignment on full-limb radiographs and conventional AP knee radiographs. Knee alignment was measured in 40 subjects (80 knees) from the Twins UK registry. Measurement of mechanical knee alignment was from FLR, and anatomic knee alignment from weight-bearing AP knee radiographs. Reproducibility was assessed by intra-class correlation coefficients and kappa statistics. Reproducibility of knee alignment for both methods was good, with intra-observer ICC's of 0.99 for both FLR and AP radiographs. The mean alignment angle on FLR was 178.9° (SD 2.1, range 173–183°), and 179.0° (SD 2.1, range 173–185°) on AP films. 58.8% of knees on FLR and 66.3% on AP films were of varus alignment. Good correlations were seen between results for FLR and AP radiographs, with ICC ranging from 0.87–0.92 for left and right knees, and kappa statistics of 0.65–0.74. Standard AP knee radiographs can be used to measure knee alignment with good reproducibility, and provide comparable results to those obtained from FLR. This will facilitate measurement of knee alignment in existing cohort studies to assess mal alignment as a risk factor of incident OA, and in clinical practice.

Commean et al, (1996) said that to determine the absolute and relative precision of geometric measurements made of below knee (BK) residua and their BK plaster positive casts using calipers, electromagnetic digitizer, optical surface scanner (OSS), and spiral x-ray computed tomography (SXCT). The experimental measurement protocol for a single measurement session was as follows: Dot markers were placed on the residuum, and volume and distances were measured using water displacement and calipers; residuum was measured using electromagnetic digitizer; residuum was scanned using three-dimensional (3D) OSS; a negative plaster cast of subject's residuum was made; the residuum was scanned using SXCT scanner. These steps were repeated at a second measurement session. Plaster positive casts were constructed and subsequently measured using the same protocol. Thirteen adult below-knee amputee volunteers (subjects) participated in the study, and nine subjects returned for a second measurement session. The study group consisted of 9 men and 4 women; 10 Caucasians and 3 African Americans. Distance measurements for all measurement devices were repeatable within 1% in vivo and within 0.5% on plaster casts; and volumes were within 1% in vivo and within 0.1% on plaster casts. Distance measurements for each device were precise within 3% in vivo and within 1% on plaster casts; and volumes were within 5% in vivo and within 6% on plaster casts when compared with caliper and water displacement measures. These measurement systems were found to be substantially equivalent in terms of repeatability and precision for measurement of lower extremity residua.

Woloszynski et al, (2010) said that the purpose of this study is to develop a dissimilarity measure for the classification of trabecular bone (TB) texture in knee radiographs. Problems associated with the traditional extraction and selection of texture features and with the invariance to imaging conditions such as image size, anisotropy, noise, blur, exposure, magnification, and projection angle were addressed. In the method developed, called a signature dissimilarity measure (SDM), a sum of earth mover's distances calculated for roughness and orientation signatures is used to quantify dissimilarities between textures. Scale-space theory was used to ensure scale and rotation invariance. The effects of image size, anisotropy, noise, and blur on the SDM developed were studied using computer generated fractal texture images. The invariance of the measure to image exposure, magnification, and projection angle was studied using x-ray images of human tibia head. For the studies, Mann-Whitney tests with significance level of 0.01 were used. A comparison study between the performances of a SDM based classification system and other two systems in the classification of Brodatz textures and the detection of knee osteoarthritis (OA) were conducted. The other systems are based on weighted neighbor distance using compound hierarchy of algorithms representing morphology (WND-CHARM) and local binary patterns (LBP). Results obtained indicate that the SDM developed is invariant to image exposure (2.5-30 mAs), magnification (x1.00 - x1.35), noise associated with film graininess and quantum mottle (< 25%), blur generated by a sharp film screen, and image size (> 64 x 64 pixels). However, the measure is sensitive to changes in projection angle (> 5 degrees), image anisotropy (> 30 degrees), and blur generated by a regular film screen. For the classification of Brodatz textures, the SDM based system produced comparable results to the LBP system. For the detection of knee OA, the SDM based system achieved 78.8% classification accuracy and outperformed the WND-CHARM system (64.2%). The SDM is well suited for the classification of TB texture images in knee OA detection and may be useful for the texture classification of medical images in general.

Ding et al, (2007) said that to describe the association between sex, age and rate of change in knee cartilage volume in adults. A total of 325 subjects (mean age 45 yrs, range 26-61) was measured at baseline and approximately 2 yrs later. Knee cartilage volume and bone size were determined using T1-weighted fat saturation magnetic resonance imaging (MRI). Height, weight, body mass index and radiographic osteoarthritis (ROA) were measured by standard protocols. Knee cartilage volume decreased by 1.5-4.2% per annum. In multivariable analysis, females had higher rates of change per annum in knee cartilage volume than males (medial tibia: -3.5%, $P < 0.001$; lateral tibia: -2.6%, $P < 0.001$ and patella: -0.8%, $P = 0.053$). The sex difference first appeared at age 40 and became more marked with increasing age at the medial tibial site only (P = 0.039). Age was significantly associated with annual change in knee cartilage volume at all three sites (beta = -0.06 to -0.12%/yr, all $P < 0.05$), and these associations were stronger in females. With the exception of the medial site (beta = -0.05/yr, P = 0.117 for ROA exclusion, and beta = -0.06%/yr, P = 0.056 for ROA adjustment), the association with age did not change when subjects with ROA were excluded from analyses or after further adjustment for ROA. Within the age range we studied, knee cartilage volume declines at a faster rate with increasing age. This is partly mediated by ROA at the medial tibial site only. Furthermore, women have substantially higher knee cartilage loss than men, and these sex differences first appear at age 40 and become more marked with increasing age, which has implications for prevention of cartilage loss from middle age.

Chapter Three

Materials & Methods

Chapter Three

Materials and Methods

3.1. Material

Conventional and digital x-ray machines, X-ray films, CDs and DVDs were used to safe the images for measuring. Allengers-525 x-ray machine was used; rating 40 KW and Power 440 ± 10 % _ AC 50/60 Hz.

3.2. Design of the study

The data of this study collected prospectively from patient with normal knee joint ‘without bone changes’ and those with bone changes therefore it is an analytical, case control study.

3.3. Population of the study

3.3.1. Group A:

The cases included in the study includes normal knee joint Sudanese patients from both genders underwent plain x-ray examination, their age ranged from (18 to 64) years old. They were come from different states and have different jobs.

Exclusion criteria for Group A:

Subjects who had eroded bone surface, osteoarthritis of joint or osteophytes, abnormal spaces between joints, fractures or trauma to the knee and any artificial knee.

3.3.2. Group B:

Group B consisted of patients with bone changes in different ages between (20 to 78 years).

3.4. Sample size and type

The sample of this study consisted of **<u>320</u>** patient. 257 of them had an AP X-Ray of Knee joint. They are divided into three groups, group ‘A’ normal x-ray of knee joint subjects **<u>106</u>** patients (55 Rt. , 51 Lt Knees), (56 males, 50 females), group ‘B’ abnormal x-ray of knee joint subjects **<u>151</u>** patients (79 Rt., 72 Lt Knees), (55 males, 96 females). The cases were selected conveniently to study the knee joint measurements. Group ‘C’ which is consisted of **<u>63</u>** patients to estimate the artificial knee size before surgery all patients that have an artificial knee joint in Sharg Elneel Hospital, Khartoum, Sudan were collected. The artificial knee joint were made of Co Cr Mo alloy for the femur and tibia material and UHMWPE as an insert material. Both female and male patients were 24 male, (15 Rt. Knee, 9 Lt. Knee), and 39 female, (20 Rt. Knee, 19 Lt. Knee) with different ages between (59 - 74) years old.

3.5. Place and duration of the study

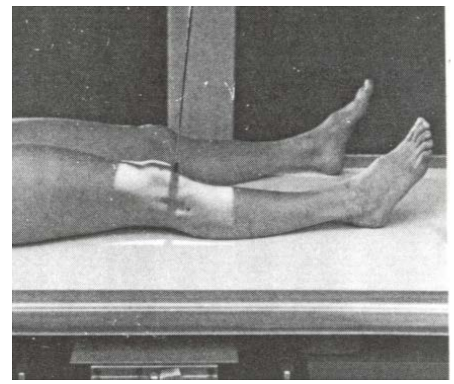
This study was done in Modern Medical Centre and Antalya Medical Centre, diagnostic departments, in the period from June 2012 to February 2015.

3.6. Method of data collection (Technique):-

Plain x-ray:- AP Knee Joint

Exposure Factors

Kv.	mAs	FFD (cm)	Grid	Focus	Cassette
65	5	100	Yes	Fine	18x24 cm



Patient Position: Supine with leg extended

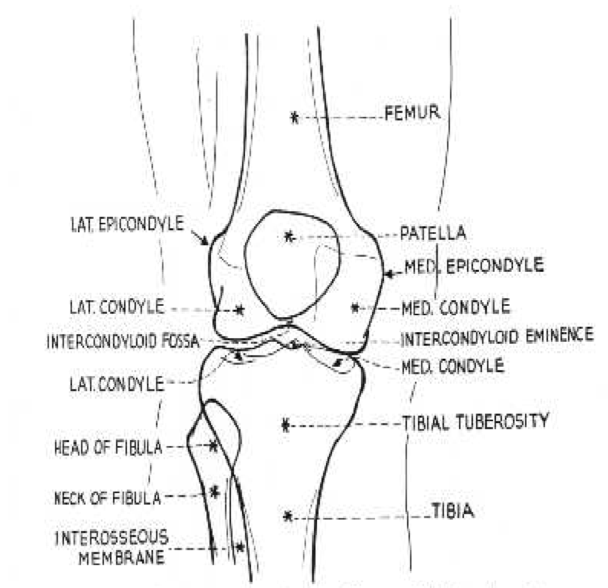
Part position:

- Adjust knee to cassette
- Slightly rotate leg medially to centralize patella

Central Ray: 5-7 degrees cephalic

Center Point: ½ inch inferior to patellar apex

Structure shown: Femorotibial joint, distal femur and proximal tibia & fibula



3.7. Bone Measurements:-

AP x-ray of knee joints for 257 patients was done using conventional x-ray, computed radiology (CR) and digital radiology (DR). Superficial simple linear surface measuring of the knee joint x-ray was done as shown in Figure (3.1.) using vertical and horizontal line as indicated by the 12 white arrows.

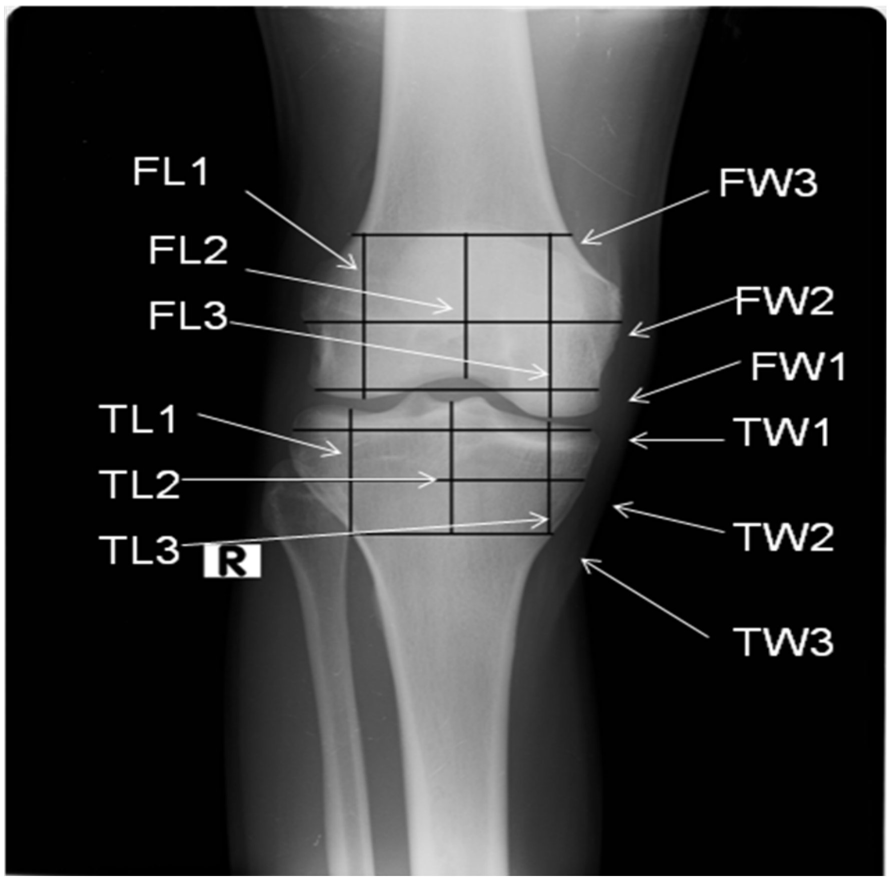


Figure (3.1.) AP plain x- ray of the knee joint illustrate the site bone measurements.

- FW1=Femur Width1. TW1 =Tibia With1.
- FW2 =Femur Width2. TW2=Tibia With2.
- FW3=Femur Width3. TW3=Tibia With3.
- FL1 =Femur Length1. TL1 =Tibia Length1.
- FL2=Femur Length2. TL2 =Tibia Length2.
- FL3=Femur Length3. TL3 =Tibia Length3.

* T=Tibia, F=Femur, L=Length, W=Width of X-Rays knee joint.
* Measurements taken by mm.

Also the Knee height and circumference was measured using the standardized procedures as described by Zhang (1998) Knee height was defined as the distance from the sole of the foot to the anterior surface of the femoral condyle of the thigh, with the ankle and knee each flexed to a 90° angle (Figure 3.2.).

Figure (3.2.) a photograph show the method of measuring the knee height

The circumference also was taken from the middle of the knee joint in the widest area in the knee with full extended knee joint Figure (3.3.).

Figure (3.3.) a photograph show the method of measuring the knee circumference

3.8. Variables of the study

The Data of this study was collected using the following variables: age, Gender, site of knee, body weight (kg), height (meter), BMI, occupations, states, (height and circumference of knee joints), knee surface measurements as shown in Figure (3.1.), period of disease (in months) and the diagnosis.

3.9. Method of data analysis:-

The data of this study were analyzed using EXCEL and SPSS, version 21 under windows, where the result include frequency distribution tables of the qualitative data and the mean ± the standard deviation of the measured data. Also the result include scatter plots reveals the relation between the body characteristics (height, weight etc… with knee joint measurement. As well as multiple regressions equation models differentiate between the symptomatic patient with bone changes and those without changes and lastly an empirical linear equation estimate the artificial knee size before the commencement of the surgical operation.

Chapter Four

Results

Chapter four
Results

This chapter showed the statistical analysis results of the study in tables and descriptive figures**.**

<u>4.1. Distribution of the variables:</u>

Table (4.1.) General Diagnosis Distribution, frequency and percentage.

Diagnosis	Frequency	Percent
Normal	106	41.2
Abnormal	151	58.8
Total	257	100.0

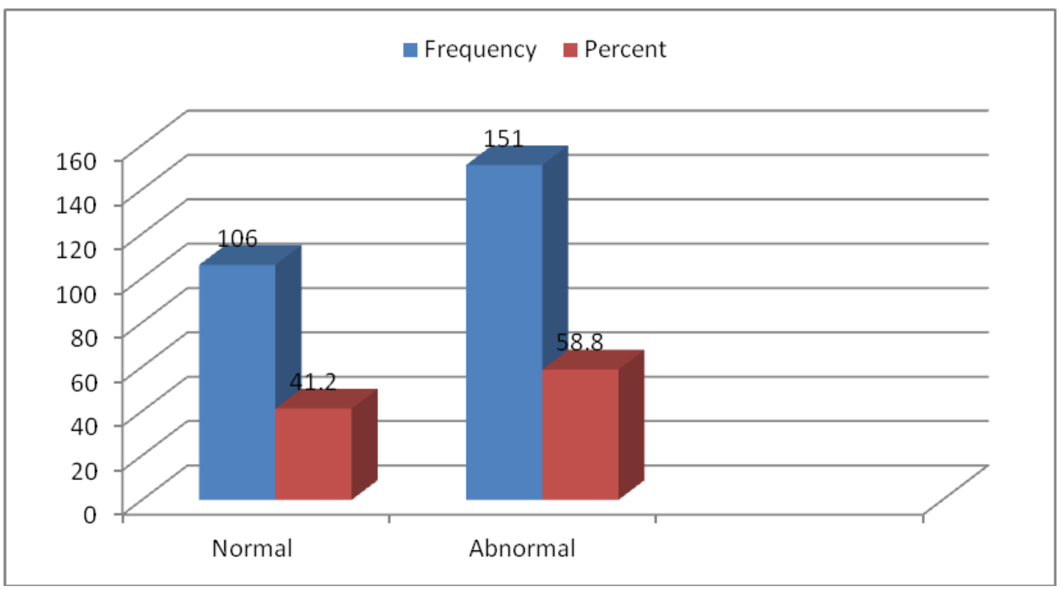


Figure (4.1.) General Diagnosis Distribution, frequency and percentage

Table (4.2.) Abnormal Diagnosis Distribution, frequency and percentage.

Abnormal Diagnosis	Frequency	Percent
1- Bone Changes	58	38.41
2- Joint Changes	9	5.96
3- Bone+Joint Changes	84	55.63
Total	151	100

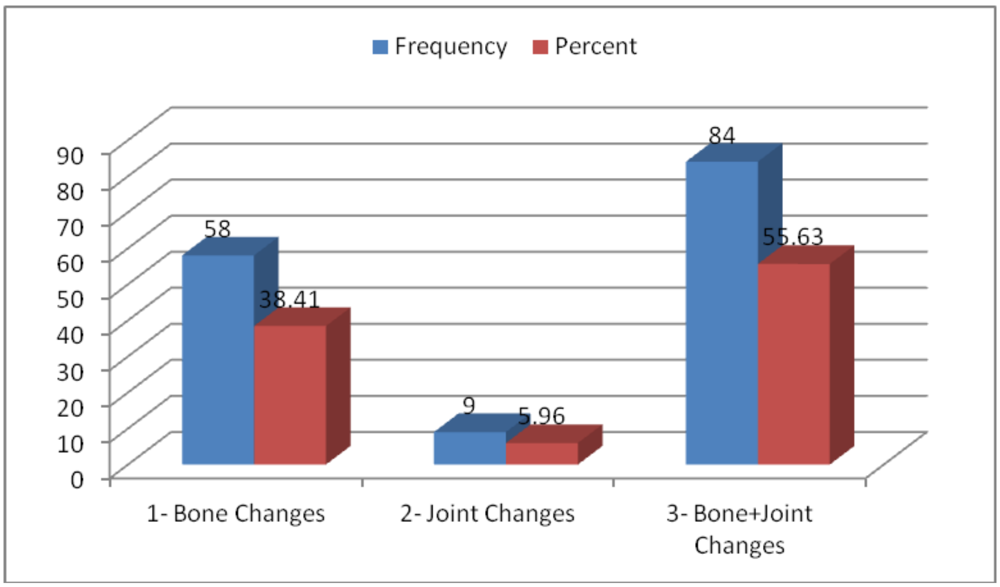


Figure (4.2.) Abnormal Diagnosis Distribution, frequency and percentage

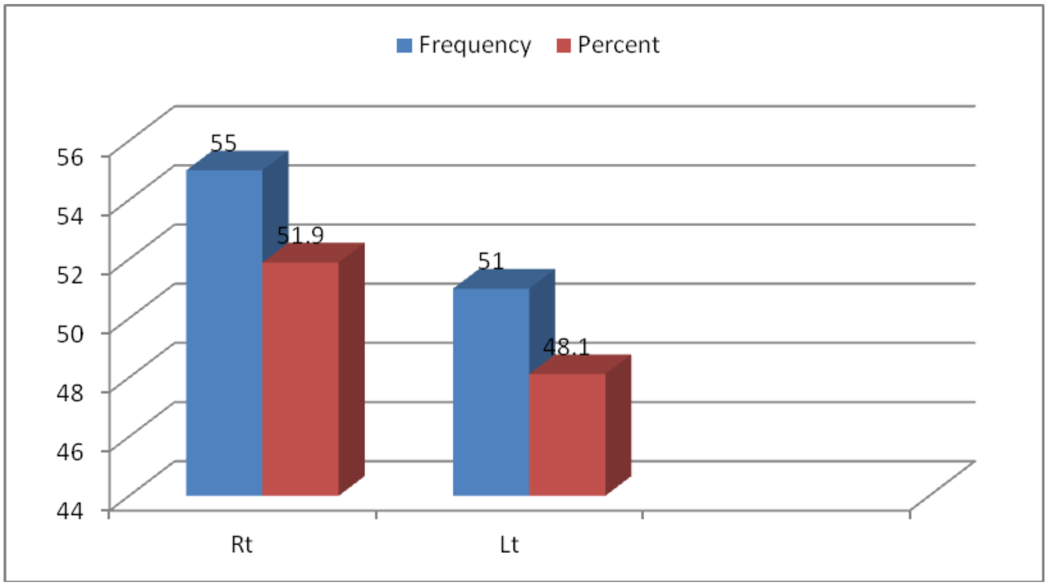
Table (4.3.) Knee site Distribution, frequency and percentage, A. and B.

A. Normal patient's

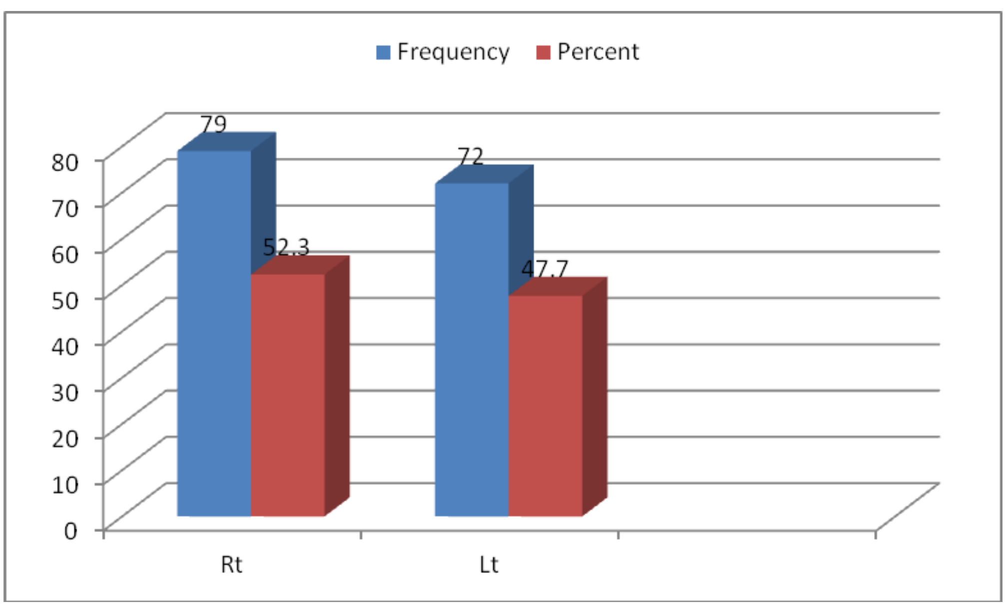
Knee Site	Frequency	Percent
Rt.	55	51.9
Lt.	51	48.1
Total	106	100.0

B. Abnormal patients

Knee Site	Frequency	Percent
Rt.	79	52.3
Lt.	72	47.7
Total	151	100.0



A. Normal patients



B. Abnormal patients

Figure (4.3.) Knee site Distribution, frequency and percentage, A. and B.

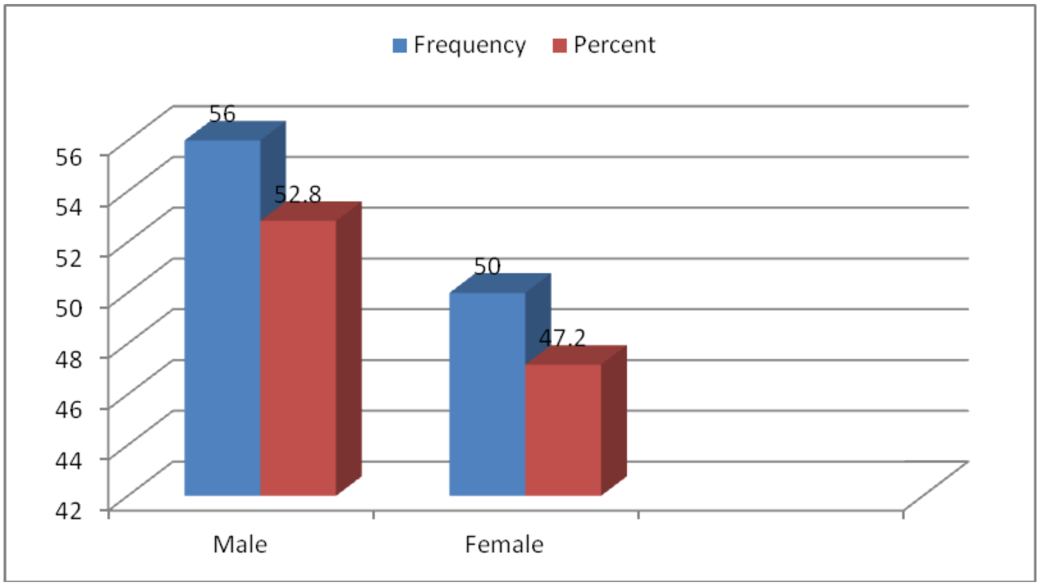
Table (4.4.) Gender Distribution, frequency and percentage, A. and B.

A. Normal patients

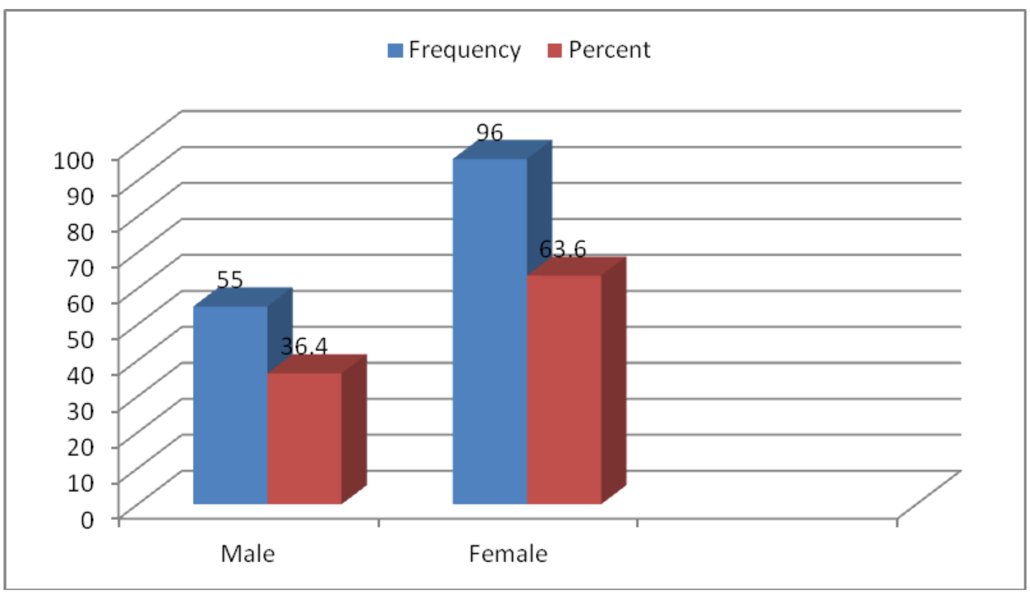
Gender	Frequency	Percent
Male	56	52.8
Female	50	47.2
Total	106	100.0

B. Abnormal patients

Gender	Frequency	Percent
Male	55	36.4
Female	96	63.6
Total	151	100.0



A. Normal patients



B. Abnormal patients

Figure (4.4.) Gender Distribution, frequency and percentage, A. and B.

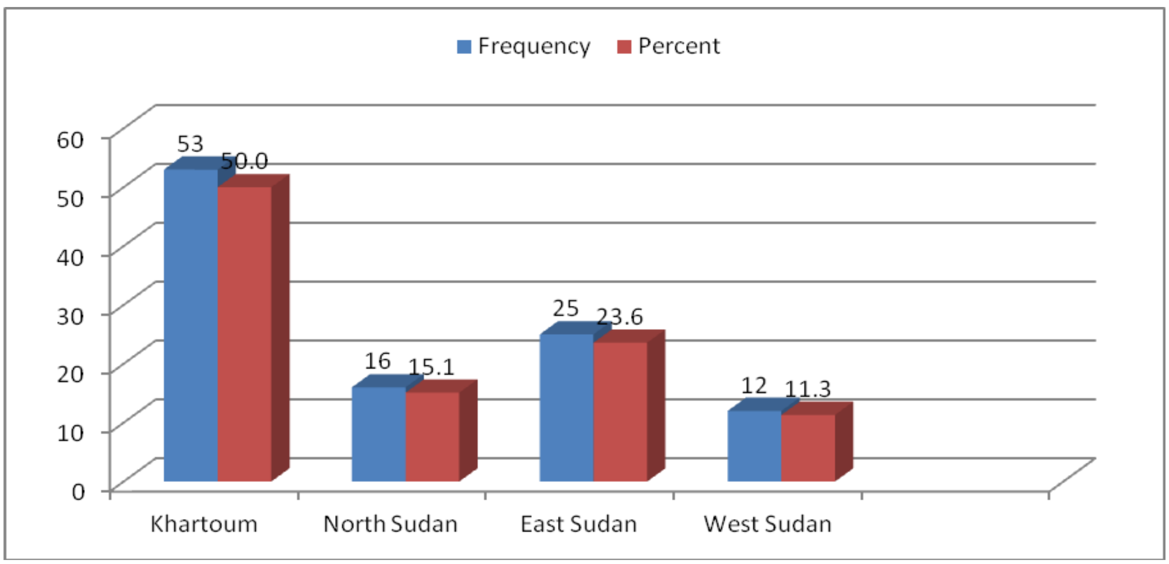
Table (4.5.) State Distribution, frequency and percentage, A. and B.

A. Normal patients

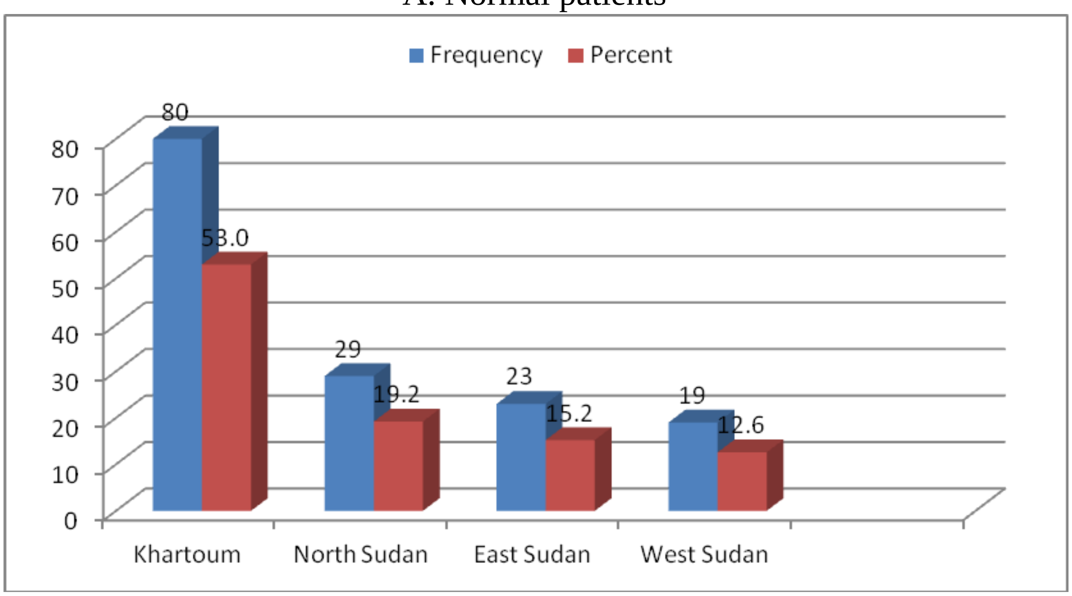
State	Frequency	Percent
Khartoum	53	50.0
North Sudan	16	15.1
East Sudan	25	23.6
West Sudan	12	11.3
Total	106	100.0

B. Abnormal patients

State	Frequency	Percent
Khartoum	80	53.0
North Sudan	29	19.2
East Sudan	23	15.2
West Sudan	19	12.6
Total	151	100



A. Normal patients



B. Abnormal patients

Figure (4.5.) State Distribution, frequency and percentage, A. and B.

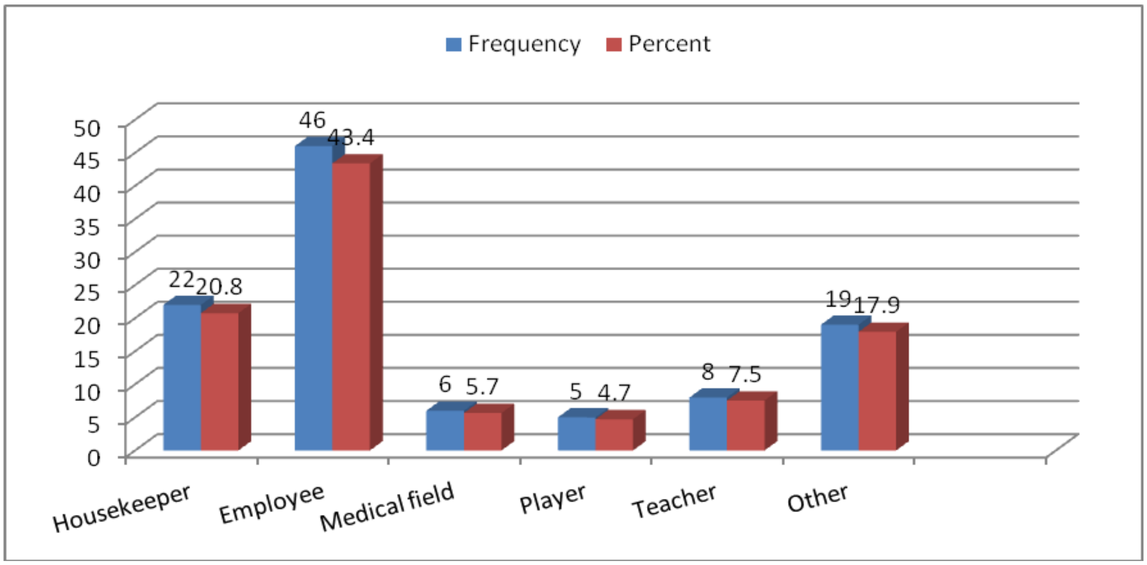
Table (4.6.) Occupation Distribution, frequency and percentage, A. and B.

A. Normal patients

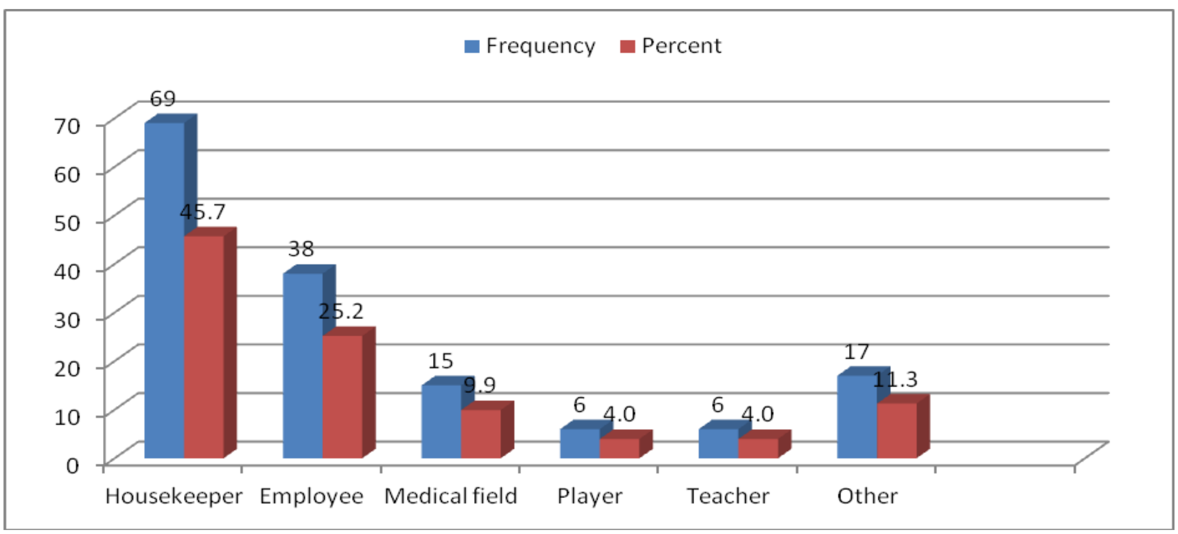
Occupation	Frequency	Percent
Housekeeper	22	20.8
Employee	46	43.4
Medical field	6	5.7
Player	5	4.7
Teacher	8	7.5
Other	19	17.9
Total	106	100.0

B. Abnormal patients

Occupation	Frequency	Percent
Housekeeper	69	45.7
Employee	38	25.2
Medical field	15	9.9
Player	6	4.0
Teacher	6	4.0
Other	17	11.3
Total	151	100.0



A. Normal patients



B. Abnormal patients

Figure (4.6.) Occupation Distribution, frequency and percentage, A. and B.

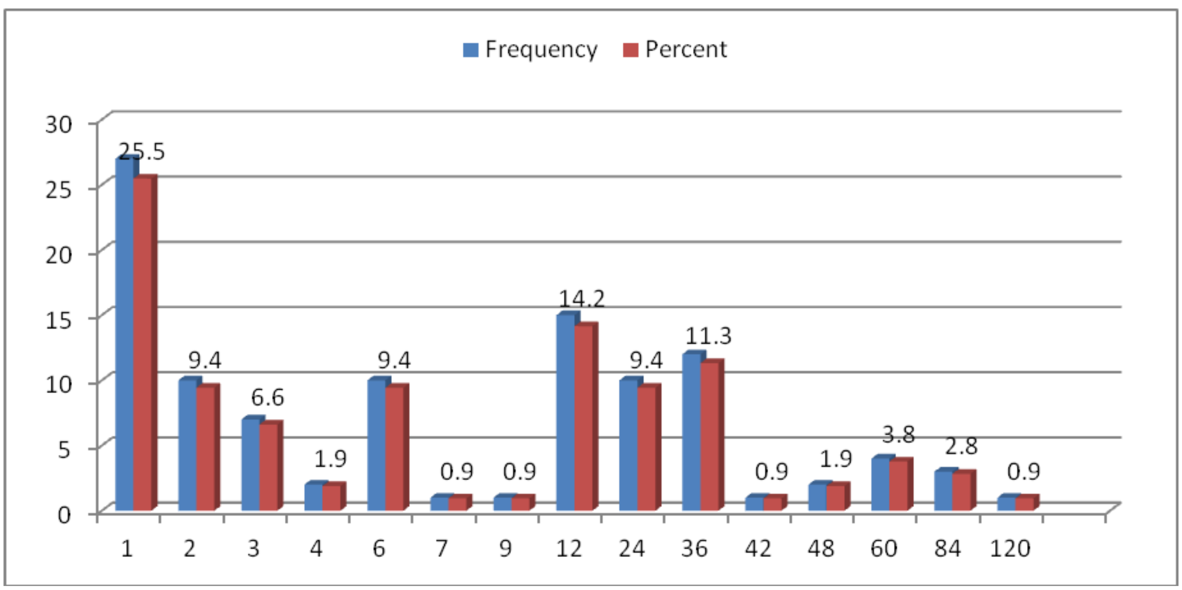
Table (4.7.) Period of disease Distribution, frequency, percentage, A. and B.

A. Normal patients

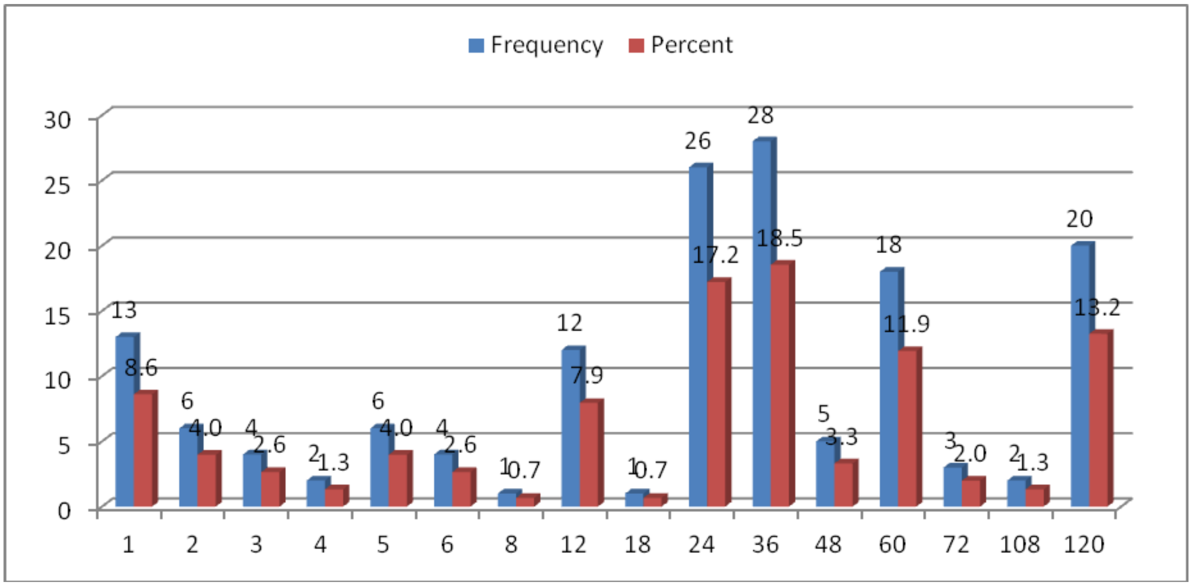
Period of disease (in month)	Frequency	Percent
1	27	25.5
2	10	9.4
3	7	6.6
4	2	1.9
6	10	9.4
7	1	0.9
9	1	0.9
12	15	14.2
24	10	9.4
36	12	11.3
42	1	0.9
48	2	1.9
60	4	3.8
84	3	2.8
120	1	0.9
Total	106	100.0

B. Abnormal patients

Period of disease (in month)	Frequency	Percent
1	13	8.6
2	6	4.0
3	4	2.6
4	2	1.3
5	6	4.0
6	4	2.6
8	1	0.7
12	12	7.9
18	1	0.7
24	26	17.2
36	28	18.5
48	5	3.3
60	18	11.9
72	3	2.0
108	2	1.3
120	20	13.2
Total	151	100.0



A. Normal patients



B. Abnormal patients

Figure (4.7.) Period of disease Distribution, frequency, percentage, A. and B.

4.2. Distribution of the means and standard Deviations (SD):

Table (4.8.): The mean ± standard deviation of patient age, height, weight, body mass index (BMI) and knee joint dimension, (Rt. & Lt.) for male and female.

Variables	Normal [Mean ± SD]		Abnormal Mean ± SD
	Male	Female	
Age	39.2 ± 12.3	42.5 ± 10.1	51.7 ± 13.3
Height of the patient	175.6 ± 6.8	166.0 ± 8.0	168.8 ± 9.5
Weight of the patient	76.8 ± 12.3	78.1 ± 15.4	81.8 ± 12.7
BMI	24.9 ± 3.7	28.3 ± 5.1	28.9 ± 5.1
Height of the Rt. knee	57.5 ± 3.6	54.2 ± 3.9	54.9 ± 4.6
Height of the Lt. knee	57.5 ± 3.6	54.1 ± 3.9	
Circumference of Rt. knee	36.9 ± 3.0	39.5 ± 5.3	39.1 ± 4.6
Circumference of Lt. knee	36. 8 ± 3.1	39.3 ± 5.3	

Table (4.9.): The mean ± standard deviation of knee measured lines for male and female.

Variables	Normal [Mean ± SD]		Abnormal Mean ± SD
	Male	Female	
FW1	6.0 ± 1.0	5.9 ± 0.7	6.2 ± 0.9
FW2	7.0 ± 2.0	5.8 ± 1.2	6.3 ± 1.4
FW3	4.0 ± 1.0	3.4 ± 0.9	3.9 ± 1.1
FL1	4.0 ± 1.0	3.0 ± 0.6	3.3 ± 0.8
FL2	5.0 ± 0.0	4.9 ± 0.1	5.0 ± 0.1
FL3	4.0 ± 1.0	3.6 ± 0.5	3.9 ± 0.6
TW1	7.0 ± 1.0	6.6 ± 0.4	6.6 ± 0.8
TW2	5.0± 1.0	4.4 ± 0.9	4.9 ± 1.1
TW3	4.0± 1.0	3.5 ± 0.4	3.7 ± 0.5
TL1	5.0± 0.0	5.1 ± 0.4	5.0 ± 0.4
TL2	5.0± 0.0	4.9 ± 0.2	5.0 ± 0.2
TL3	4.0± 0.0	3.8 ± 0.3	4.0 ± 0.4

* T=Tibia, F=Femur, L=Length, W=Width.

Table (4.10.): t-test result show the significant differences between the male and female in respect to knee bone surface measurements

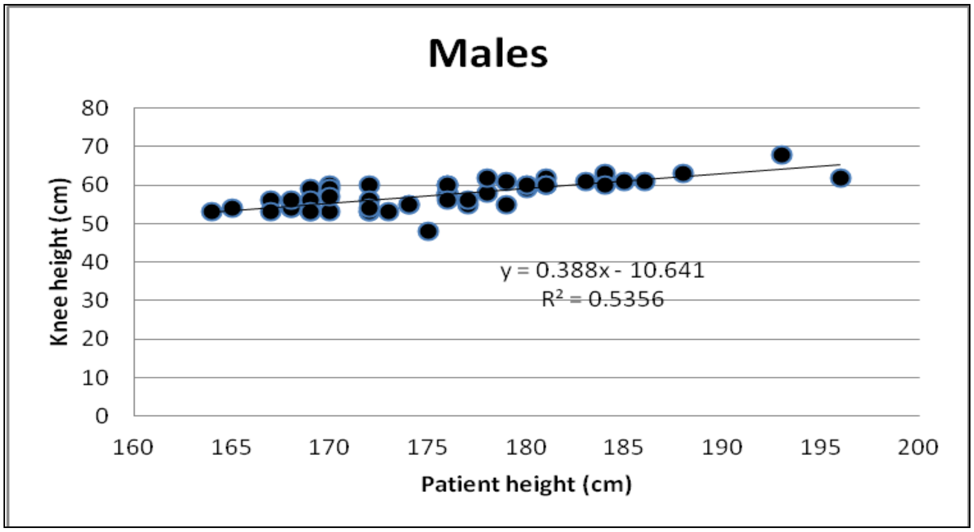
Independent Samples Test (Gender for normal)		
		t-test for Equality of Means
	Sig.	t
FW1X	**0.043**	**2.618**
FW2X	**0.016**	**3.051**
FW3X	**0.046**	**3.178**
FL1X	**0.002**	**3.790**
FL2X	0.133	3.299
FL3X	0.054	2.819
TW1X	**0.024**	**3.066**
TW2X	0.071	2.950
TW3X	0.067	3.063
TL1X	0.312	2.987
TL2X	0.792	0.715
TL3X	0.279	3.026

Table (4.11.): The mean ± standard deviation of artificial knee stickers for male and female

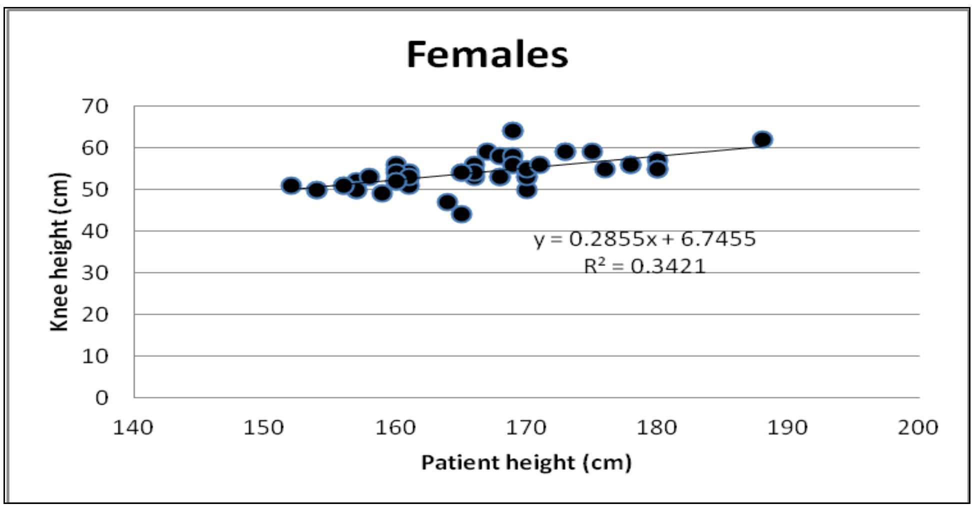
Variables	Male Mean ± SD	Female Mean ± SD
Femur Size	09.7 ± 1.9	07.0 ± 2.2
AP Femur	64.1 ± 3.3	59.7 ± 3.6
ML Femur	71.8 ± 2.5	67.8 ± 3.6
Tibia Size	09.2 ± 2.0	06.2 ± 1.9
AP Tibia	48.3 ± 2.2	45.0 ± 2.1
ML Tibia	74.6 ± 3.2	69.3± 3.7
Stem Length	36.9 ± 2.5	35.1 ± 0.8
Insert Size	09.2± 2.0	06.2 ± 1.9
Thickness Size	11.8 ± 2.0	11.0 ± 1.8

Table (4.12.) t-test results showed significant differences between male and female in respect to knee measurement; height and circumferences

Gender	t-test for Equality of Means	
	t	Sig. (2-tailed)
Height of Rt. Knee	4.530	0.0001
Height of Lt. knee	4.623	0.0001
Circumference of Rt. knee	3.192	0.002
Circumference of Lt. knee	2.966	0.004

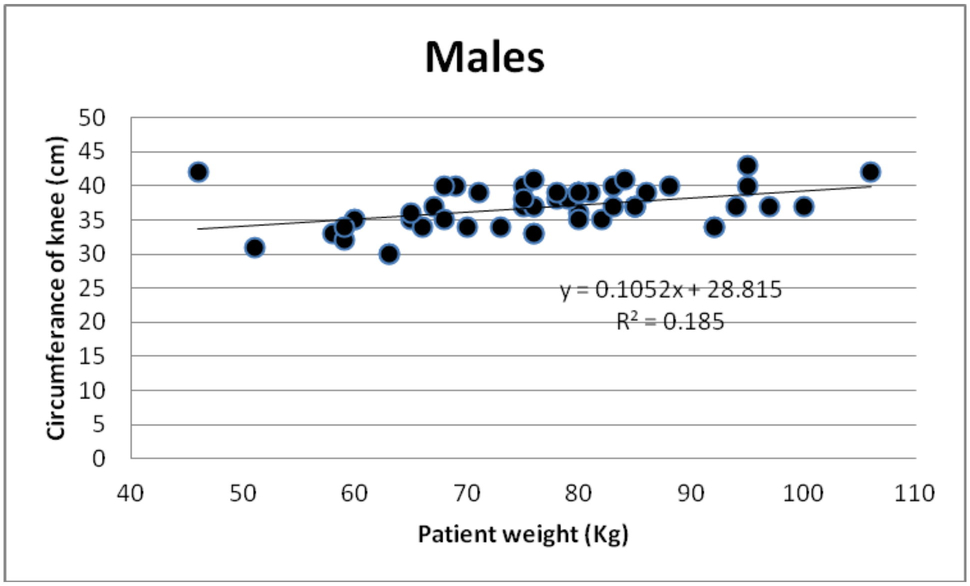


(A)

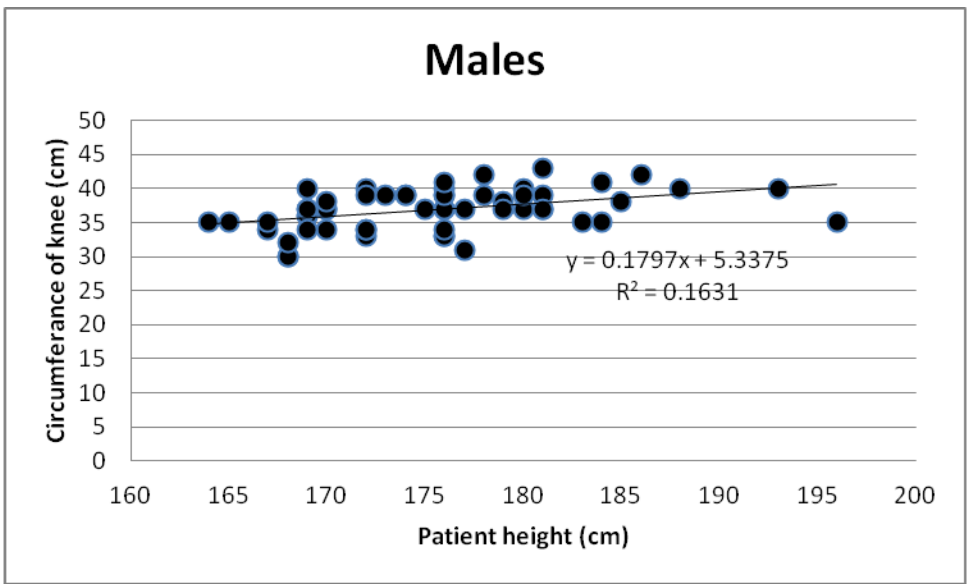


(B)

Figure (4.8.): scatter plot show a direct linear relationship of the knee height and patient height for male in (A) and female (B)

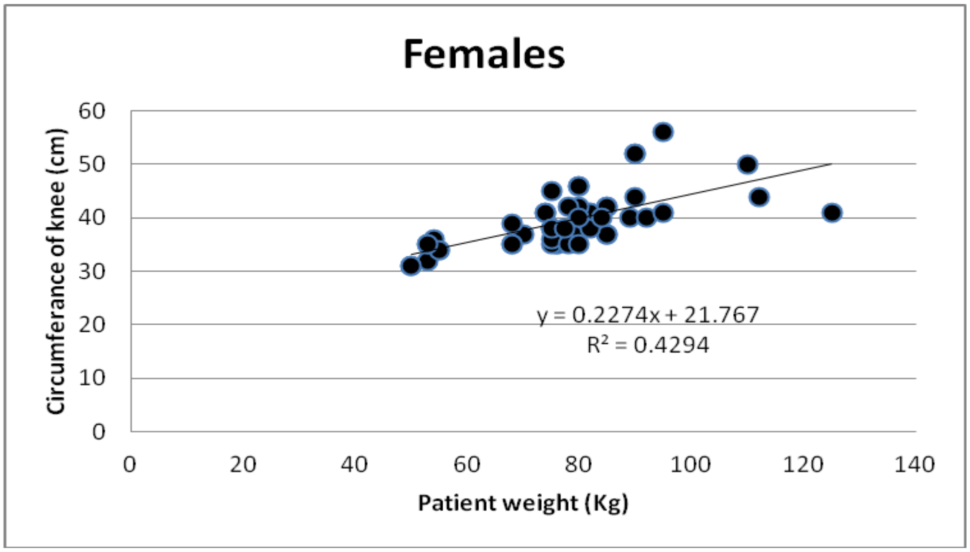


(A)

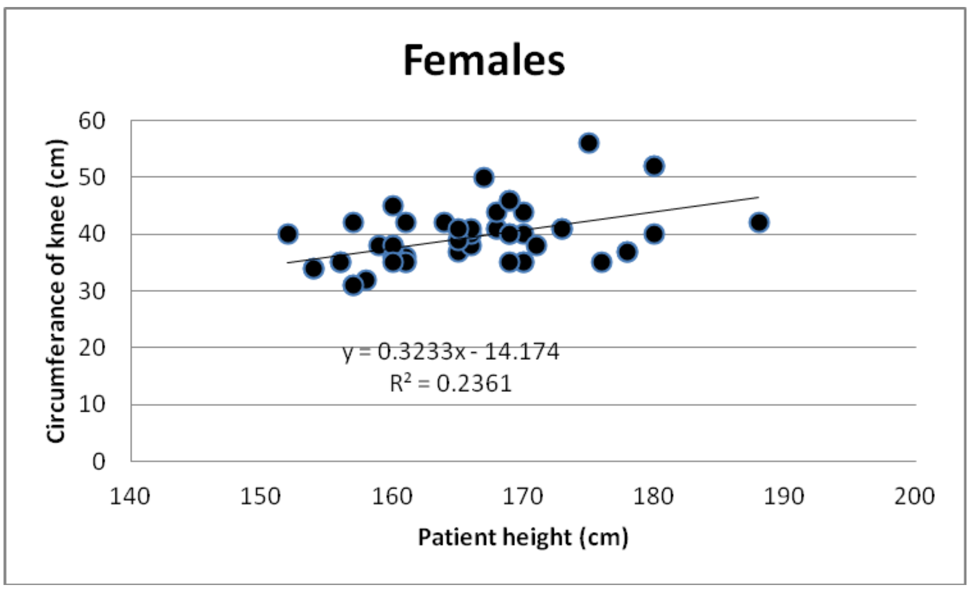


(B)

Figure (4.9.): scatter plot show a direct linear relationship of the knee circumference for males and patient weight in (A) and height (B)



(A)



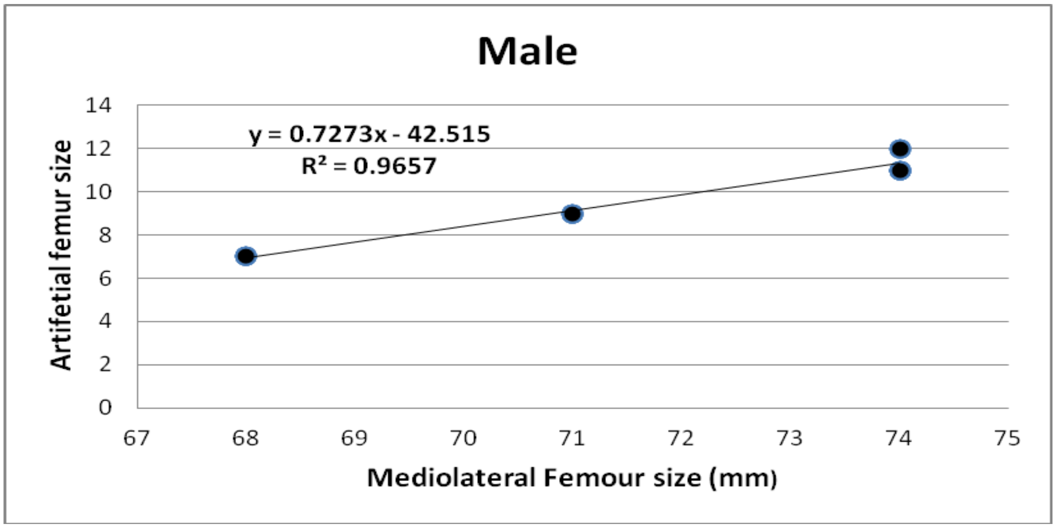
(B)

Figure (4.10.): scatter plot show a direct linear relationship of the knee circumference for females and patient weight in (A) and height (B)

Table (4.13.): A significant t-test between the normal knee in x-ray and abnormal one concerning the height and circumference of the knee.

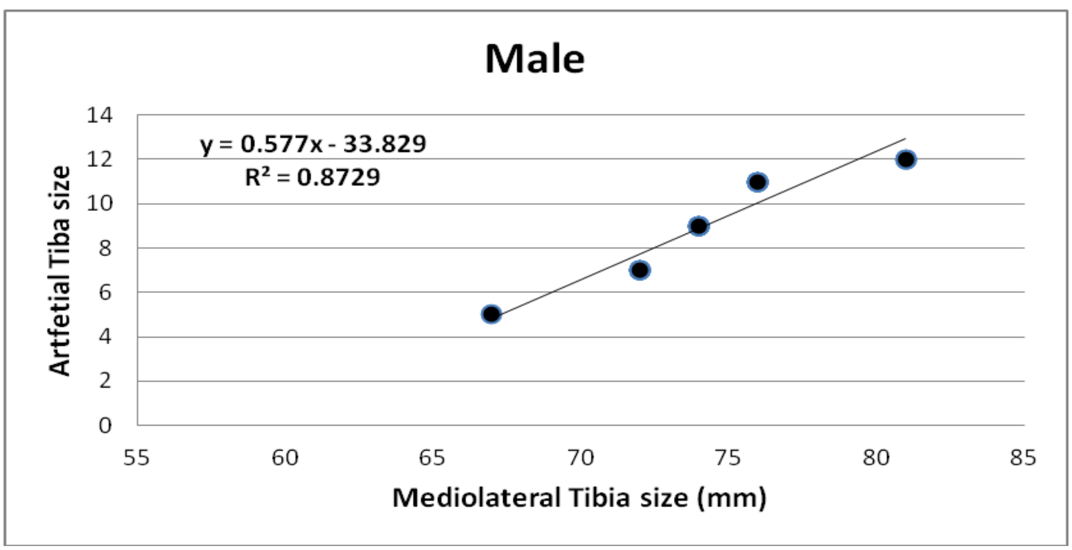
Variable	***t***	*p*
Height of Rt. Knee & Height of Lt. knee	1.84	0.067
Circumference of Rt. knee & Circumference of Lt. knee	3.69	0.0001

The artificial femur size (AFS) for male increases by 0.73 unit/1 mm of mediolateral femur size (MLFS), where the artificial size can be predicted using the following equation: AFS= (0.7273xMLFS) - 42.515 as seen in the **Figure (4.11.)**, (A)



(A)

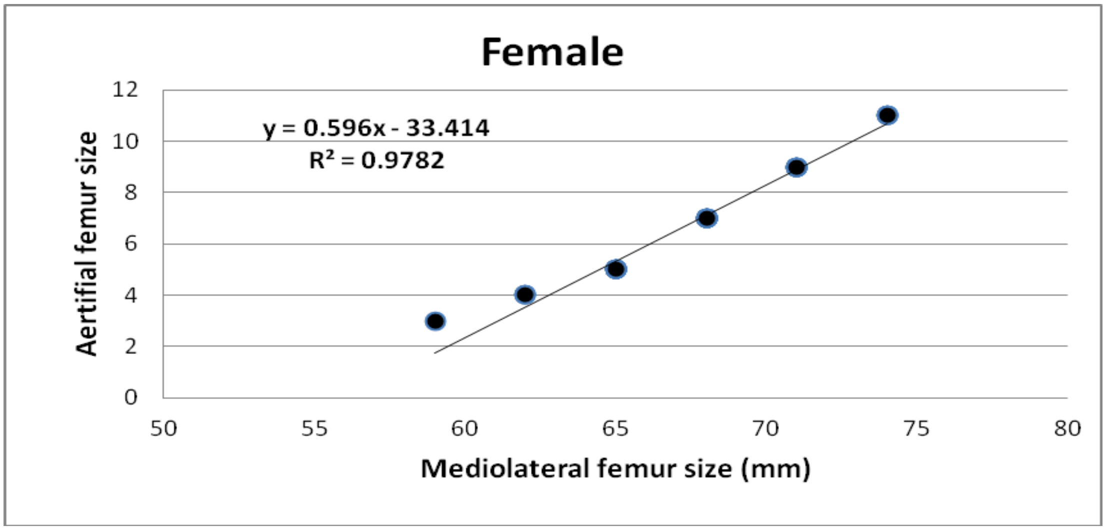
The artificial tibia size (ATS) for male increase by 0.58unit/1 mm of mediolateral tibia size (MLTS), where the artificial size can be predicted using the following equation: ATS= (0.577xMLTS) - 33.829 as seen in the **Figure (4.11.)**, (B)



(B)

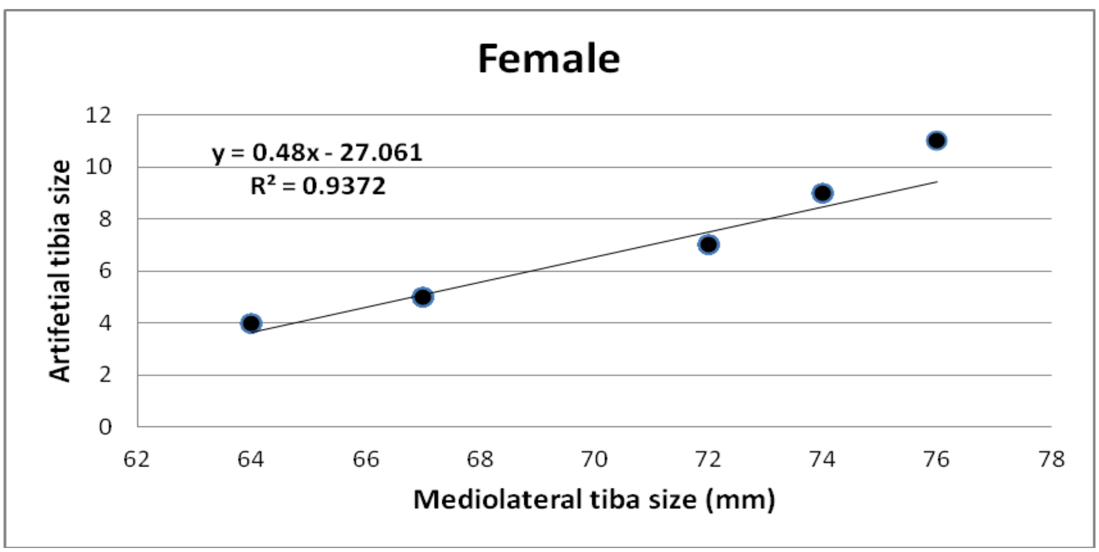
Figure (4.11.): scatter plot show a direct linear relationship of the mediolateral femur and tibia size with the artificial knee for male.

The artificial femur size (AFS) for female increases by 0.60 unit/1 mm of mediolateral femur size MLFS), where the artificial size can be predicted using the following equation: AFS= (0.596xMLFS) -33.414as seen in the (Figure 4.12, (A)



(A)

The artificial tibia size (ATS) for female increase by 0.48unit/1 mm of mediolateral tibia size (MLTS), where the artificial size can be predicted using the following equation: ATS= (0.48xMLTS)- 27.061 as seen in the (Figure 4.12, (B)



(B)

Figure (4.12.): scatter plot show a direct linear relationship of the mediolateral femur and tibia size with the artificial knee for female.

Chapter Five

- Discussion
- Conclusion
- Recommendations
- Outcome of this study

Chapter Five
Discussion, Conclusion and Recommendations

5.1. Discussion

The results of this study revealed that; there is a difference between male and female body mass index which is equal to 24.9 ± 3.7 Kg/m2 and 28.3 ± 5.1 Kg/m2 for male and female respectively. This differences were significant at p = 0.05 using t-test. Similarly the height which is 175.6 ± 6.8 cm and 166.0 ± 8.0 cm respectively were significantly different at p = 0.05, although their weight show insignificant variation which equal to 76.8 ± 12.3 Kg and 78.1 ± 15.4 Kg for male and female respectively. This means that the increases in female BMI attributed to their weight which is not comply with their height as the case in male (Table 4.8.).

An ordinary tape measure would satisfy the need for simple, readily available equipment to measure joint circumference, an acknowledged index of joint inflammation. The results of this study indicate that measurement of the knee with an ordinary tape measure provides reproducible results when used by both single and multiple observers. This result agrees with Nicolas et al, (1976).

Knee height was measured using the standardized procedures as described by Zhang [14]. Also in respect to height and circumference of knee the differences between Rt. and Lt. Knee for normal patients were inconclusive. But if we consider gender there is significant difference between male and female regarding the height and circumference of the knee at $p = 0.05$ using t-test (Table 4.8.) with the a mean value for knee height of 57.5 ± 3.6 cm and 54.2 ± 3.9 cm for male and female in favor of male. In correlation prospective, the height of the knee in male and female showed a significant linear association with patient height; where in males the height of the knee increases by 0.39 cm per each one cm of the patient height, while for females it increases by 0.28 cm for each one cm of the patient height. This relation dictate that the height of the knee in males were mostly longer than that of the female in respect to their higher coeffecient (Figuer 4.8. A & B).

Similarly the circumference of the knee for male and female were 36.9 ± 3.0 cm and 39.5 ± 5.3 cm respectively, in favor of female this differences were significant at p = 0.05 using t-test. The circumference of the knee was significantly associated with the patient height and weight together for male and female separately. The knee circumference increases by 0.11 cm/Kg of patient weight and by 0.18 cm/cm of patient height for male as shown in Figure (4.9. A & B). For female the knee circufrence in respect to patient weight increased by 0.23 cm/Kg of body weight while for height it increases by 0.32 cm/cm of height. This result also dictate that; circumferance of knee for female is more than that of male. This increases indicated by the increment of the linear coeffecient increase of weight and height Figure (4.10. A & B).

The result of this study found that, manifestation of bone changes (pathology) in x-ray in symptomatic patients can be predicted before performing x-ray examination. This result showed that there is a multiple linear regression between the appearance of the disease in bone or not for symptomatic patient and age, BMI and period of disease in moths. The coefficient of these associations can be used in a multiple regression equation to predict the presence or absence of the disease prior x-ray examination as follows: *knee state* = (*Age×0.009*) + (*period of disease×0.003*) + (*BMI×0.015*), if the result ≤ 1most likely there is no change will be detected in the x-ray if the outcome ≥ 2 pathological changes will be perceptible. A strong association was found between high body mass index and the presence of knee osteoarthritis in study conducted in odds ratio 3.90 for highest versus lowest quartile of BMI; This result is in agreement with Manek et al. (2003).

Recent study in America found that for a woman of normal height, weight loss of only 5 kg reduces the risk of OA by more than 50%. Estimated that substantial weight loss e.g. obese to overweight, or overweight to normal weight, could prevent 33% of OA in women and 20% in men.

The result of “knee” bone surface measurements in AP x-ray, which includes the measurement of the width and length of the femur and tibia; where each of these measurement consisted of three measurements as shown in Figure (3.1.), it has been found that there is 5 measurements out of 12 showed significant differences between male and female for normal patients. These measurement include femur width (FW1, FW2 and FW3), femur length (FL1) and tibia width (TW1) at $p = 0.05$ using t-test in Table (4.10.). This result showed that the femur width measurement in it is three locations were different in sizes than that of the female i.e. it exceed the size of the female in Table (4.10.) similar result were achieved concerning the FL1 and TW1. In the same essence the result of this study found that knee joint measurement in respect to the presence of bone changes (pathology) there is only four measurements showed significant association with the diagnosis (normal = 1 and abnormal = 2). They include tibia length (TL1 and TL2), tibia width (TW3) and femur length (FL1), with a multiple regression coefficient of 0.383, 0.86, and 0.625 and -0.294 cm respectively per measurement of the respective site. This result implies that determination of bone changes in x-ray can be determined quantitatively through this equation as follows: *Diagnosis = (TL2×0.86) + (FL1×-0.294) + (TW3×0.625) + (TL1×0.383) – 5. 846*. If the value of diagnosis equal one or less there is no remarkable boney changes, if it is 2 or more it is most likely.

Annually there were over 500,000 total knee replacement procedures performed in the US. It is projected that by 2030, the volume of this procedure will increase to over 3.48 million per year due to the aging baby-boomers, increased obesity and indications for total knee replacement that extend to both younger as well as older patients.1 From 2000 to 2006, the Medicare total knee replacement rate overall in the United States increased by 58%, from 5.5 to 8.7 per 1,000.2 (MMWR Weekly, 2009).

The data that was collected for measuring artificial knee for male and female was femur size, AP (the depth of the joint) and ML (the width of joint) and tibia size, its AP and ML also is measured. Stem length and insert size and its thickness are also collected. Table (4.11.) shows their means and standard deviations for male and female. In this study it has been found that the mediolateral femur measurements for male is equal to 6.4 ±1.03 and 5.9± 0.7 for female and the mediolateral tibia measurements is equal to 6.8 ± 0.9 for male and 6.3 ± 0.6 for female. These differences were significant at p=0.05 using the t-test with t=2.62 for male and t=3.07 for female and p=0.04 and 0.02 respectively. The mediolateral femur and tibia measurement were significantly correlated with the height and circumference of the knee, as well these measurements were correlated significantly with the artificial femur and tibia size. The artificial femur size (AFS) for male increases by 0.73 unit/mm of mediolateral femur size (MLFS), while the artificial tibia size (ATS) for male increase by 0.58unit/ mm of mediolateral tibia size (MLTS). Similarly the artificial femur size (AFS) for female increases by 0.60 unit/mm of mediolateral femur size MLFS) and the artificial tibia size

(ATS) for female increase by 0.48 unit/mm of mediolateral tibia size (MLTS).

5.2. Conclusion

This study found that the height and circumference of the knee of male and female were significantly different. The height of the knee significantly associated with the height of the patient where this height can be estimated for male and female using these equations: *Knee height = (0.39 × patient height) - 10.6* and *Knee height = (0.29 × patient height) + 6.7* for male and female respectively. The circumference of the male and female were associated with the height and weight of patient as follows: *Knee circumference = (weight × 0.08) + (height×0.13) + 7.7* and *Knee circumference = (weight × 0.19) + (height×0.16) - 2.1* for male and female respectively.

This study found that the *diagnosis = (TL2×0.86) + (FL1×-0.294) + (TW3×0.625) + (TL1×0.383) – 5. 846*. Diagnosis= 1 normal knee, 2 abnormal knees.

Concerning the artificial knee size measurement this study showed that the mediolateral femur and tibia measurement were significantly correlated with the height and circumference of the knee, as well these measurements were correlated significantly with the artificial femur and tibia size. As well as the size of artificial femur and tibia for male and female can be estimate using the following equation: for male; femur *AFS= (0.73 x MLFS) - 42.5* and tibia *ATS= (0.58 x MLTS) - 33.8.* Similarly for female, femur *AFS= (0.59 x MLFS) -33.4* and tibia *ATS = (0.48xMLTS) -27.1*

In summary this study showed that, it is possible to identify the symptomatic knee joint patients whom will reveal bone changes in plain x-ray using only physical characteristics as well as to quantify the presence of these changes in the bone through a multiple regression linear equation using bone measurement in the x-ray as input. Also it is possible to determine the size of the artificial femur and tibia before surgery.

5.3. Recommendations:-

- Plain x-ray knee must be used as basic imaging modality for measurements.
- The new protocol for artificial knee measurements should be adopted by orthopedic surgeon after they investigate it is feasibility in Sudan before surgery is recommended.
- Further volumetric knee measurements (3D) using CT can be investigated and compare with this study.
- Further study about the use of US in assessment of knee joint diseases is recommended.
- Further studies of the knee normal dimensions in specific age groups using different modalities are recommended.
- Further studies of the knee measurement in different tribes in Sudan using different modalities are recommended.
- For the recent introduction of artificial knee in Sudan, further study in the use of plain and CT pre and post-surgery for knee measurements is recommended.

5.4. Outcome of this study:-

1. The outcome of this study provides full knowledge of Sudanese knee characterization. This data will help in their artificial knees accurate size.

2. Two scientific papers was prepared and published in peer reviewed Journals.

3. One conference presentation (International) was presented.

4. One local presentation was presented.

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Appendices

Appendix A: -   X-rays AP Normal Knee Joints

 Figure A-1 M, 36 yo	 Figure A-2 M, 22 yo
 Figure A-3 M, 65 yo	 Figure A-4 M, 37 yo
 Figure A-5 F, 30 yo	 Figure A-6 F, 30 yo

Figure A-7
M, 29 yo

Figure A-8
F, 35 yo

Figure A-9
M, 39 yo

Figure A-10
M, 46 yo

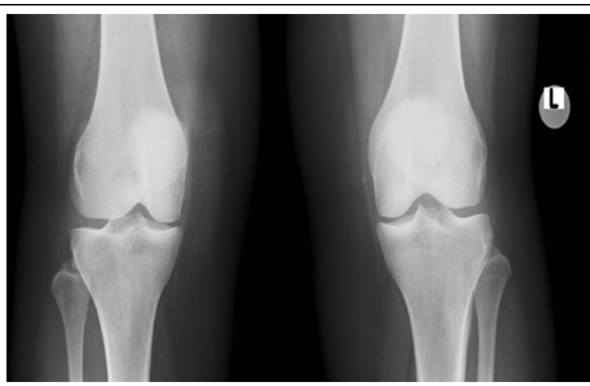

Figure A-11
F, 38 yo

Figure A-12
F, 42 yo

Appendix B: - X-rays AP Abnormal Knee Joints

Figure A-13
M, 58 yo

Figure A-14
M, 50 yo

Figure A-15
M, 20 yo

Figure A-16
F, 49 yo

Figure A-17
M, 69 yo

Figure A-18
F, 78 yo


Figure A-19
F, 50 yo


Figure A-20
M, 45 yo


Figure A-21
M, 45 yo


Figure A-22
M, 53 yo


Figure A-23
M, 75 yo

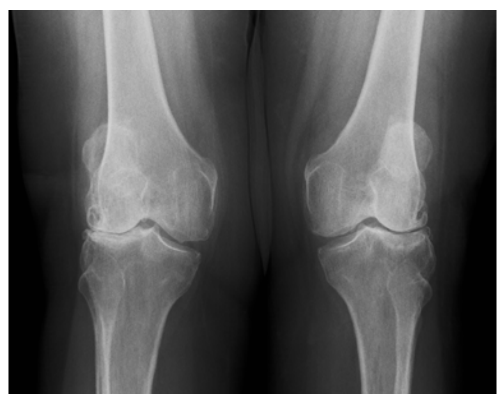
Figure A-24
F, 65 yo

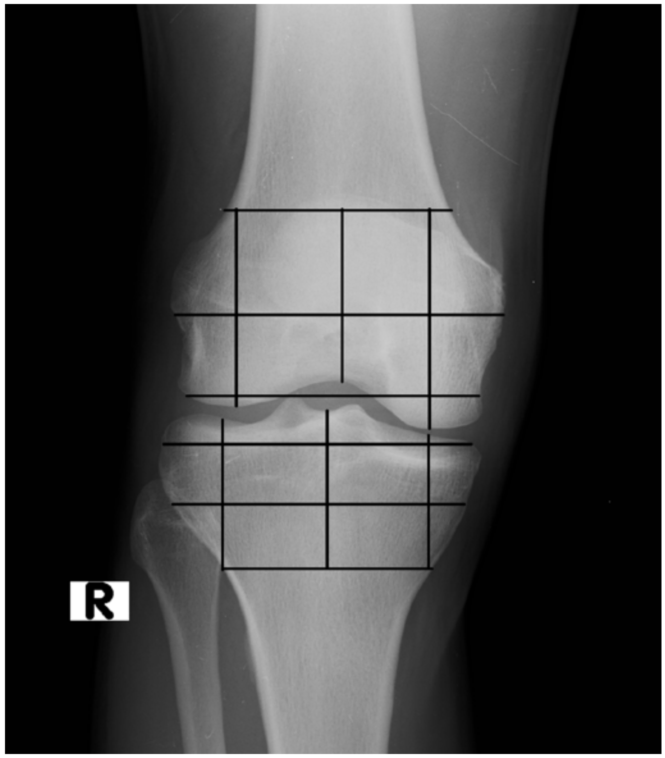

Figure A-25/ M, 28 yo

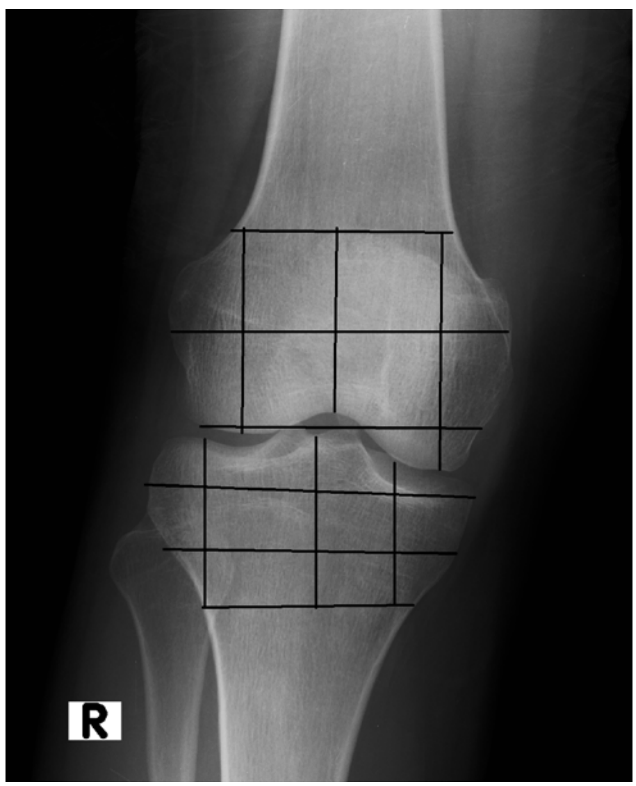

Figure A-26/ M 35 yo

إقرار وقبول

أقر أنا ....

بموافقتي على إجراء فحوصات أشعة لمفصل الركبة وإعطاء المعلومات الشخصية اللازمة في الأستبيان المرفق بغرض البحث المقدم من الباحثة / بدرية عوض الأمين مصطفى.

الأسم.....................................

الامضاء ....

التأريخ ....

....

Consent Form

I..consent that I agree to do a plain X-ray for my knee joint and give the required personal information for the PhD questionnaire that presented by the researcher/ Badria Awad Elamin.

Name:..

Signature ....

Date..

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Research Article

Characterization of symptomatic Knee Joint in Sudanese

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Abstract: Knee Joint is one of largest and complex joint in the human body. The aim of this study was to characterize symptomatic knee joints in Sudanese population by using height and circumference of knee joint to predict pathological changes that appear in the planner x-ray film in advance. A total of 257 symptomatic knee joints were measured. One hundred and six showed no change in the x-ray film 'normal', (56 male and 50 female), 151 of symptomatic patient's showed change of knee joint in the plain x-ray 'diseased' (55 males and 96 females). Their age range between 18-65 years, bio-data such as height, weight, body mass index heights and circumferences of knees were recorded. In this study we found that there is a significant difference between the height and circumference of the knee for male and female, but there is inclusive differences regarding Rt and Lt knee in normal cases. While the circumference of the knee showed a significant difference between those with remarkable x-ray changes and the symptomatic one without obvious x-ray changes. In conclusion we can estimate the symptomatic patient without changes in X-ray from those with changes by using their age, body mass index and period of disease in a multi-regression equation to predict each groups where the index of possibility increase 0.009, 0.003 and 0.015 for age, period of disease and body mass index respectively; where index one indicate no change in x-ray and index two indicate presence of changes.
Keywords: Knee joint, Circumference, BMI.

INTRODUCTION

The knee joint is not only one of the largest, but also one of the most complex joint in the human body. It is able to withstand significant strain and injury risks in everyday and occupational life as well as in sports. However, people with anatomical problems such as bowlegs or knock knees may experience pain. Normal age related processes and excess weight, as well as physical inactivity, can lead to wear and tear on the joint [1].

The circumference of the knees and thighs at three locations was measured in 10 patients on two consecutive occasions by three observers. Analysis of the results for inter observer, intra observer and among-patient variation established that a change in circumference noted by different observers on two different days is significant if it exceeds 1-5 cm at the midpatella, 2-7 cm at 7 cm above, and 3-5 cm at 15 cm above the patella. If a single observer performs both measurements, the change need exceed only 1-0, 2-0, and 2-7 cm, respectively, to be significant [2].

A strong association was found between high body mass index and the presence of knee osteoarthritis in study conducted in odds ratio 3.90 for highest versus lowest quartile of BMI [3].

The main objective of the current study was to characterize the knee joints in Sudanese population by using Plain x-ray and MRI to alleviate the differences that arise in the knee joints measurements which attributed to the characteristic and pathological changes.

MATERIALS AND METHODS

This study was carried in Khartoum state – Sudan in the period from June/2012 to September/2014 in the Modern Medical Centre and Antalya Medical Centre. All measurements and imaging acquisitions and diagnosis were carried by the same staff and author to insure reproduce ability and accuracy. The sample of this study consisted of 257 symptomatic knee joints patient, all patient were examined by planner x-ray for knee. One hundred and six showed no change in the X-ray film 'normal', (56 male and 50 female), 151 of symptomatic patient's showed change of knee joint in the plain X-ray 'diseased' (55 males and 96 females), their age range between (18-65) years. Bio-data such as height, weight, body mass index and different heights and circumferences of knees were recorded. The heights were taken by normal tape in centimeters with the patient sitting the knee joint at 90 degrees with the ankle joints. The length was taken from upper knee to the lower sole of foot. The circumference also was taken from the middle of the knee joint in the widest area in the knee with full extended knee joint. The data were analyzed by Microsoft EXCEL and statistical package for social science SPSS version 16 under windows.

RESULTS AND DISCUSSION

The results of this study revealed that; there was a difference between male and female body mass index (BMI) although their weight showed minor variation, and this proved by study performed by Story *et al.* [4] and study performed by Bellisle *et al*. [5], Table 1 & 2. Also in respect to height and circumference of knee there were no remarkable differences between Rt. and Lt. Knee for normal patient also this agree with study performed by HIckson *et al*. [6]. But if one considered gender there were significant differences between male and female regarding the height and circumference of the knee at $p = 0.05$ using t-test (Table 2).

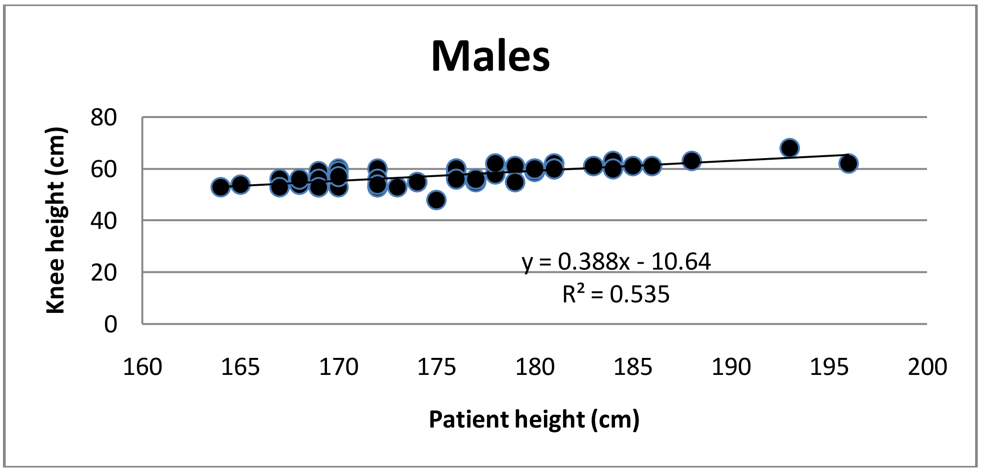
Table 1: The mean ± standard deviation of patient age, weight, height, body mass index and knee joint dimension (Rt. & Lt.) for male and female)

Variables	Male Mean ± SD	Female Mean ± SD
Age	39.2 ± 12.3	42.5 ± 10.1
Height of the Patient	175.6 ± 6.8	166.0 ± 8.0
Weight of the Patient	76.8 ± 12.3	78.1 ± 15.4
BMI	24.9 ± 3.7	28.3 ± 5.1
Height of the Rt. Knee	57.5 ± 3.6	54.2 ± 3.9
Height of the Lt. Knee	57.5 ± 3.6	54.1 ± 3.9
Circumference of the Rt. Knee	36.9 ± 3.0	39.5 ± 5.3
Circumference of the Rt. Knee	36.8 ± 3.1	39.3 ± 5.3

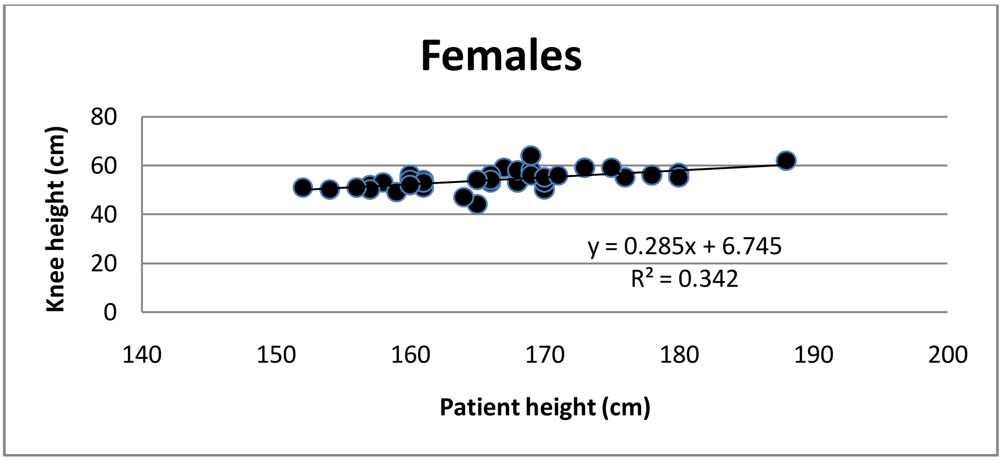
Table 2: t-test results showed significant differences between male and female in respect to knee measurement; height and circumferences

Gender (1)	t-test for Equality of Means	
	t	Sig. (2-tailed)
Height of Rt. Knee	4.530	.000
Height of Lt. knee	4.623	.000
Circumference of Rt. knee	3.192	.002
Circumference of Lt. knee	2.966	.004

The height of the knee in male and female showed a significant correlation the patient where in males the it increases by 0.39 cm per each one cm of the patient height, while for females it increase by 0.28 cm for each one cm of the patient height. This relation dictate that the height of the knee in male were longer than that of the female in respect to higher coeffecient as well as the height of male which exceed the female (Fig. 1 A & B).



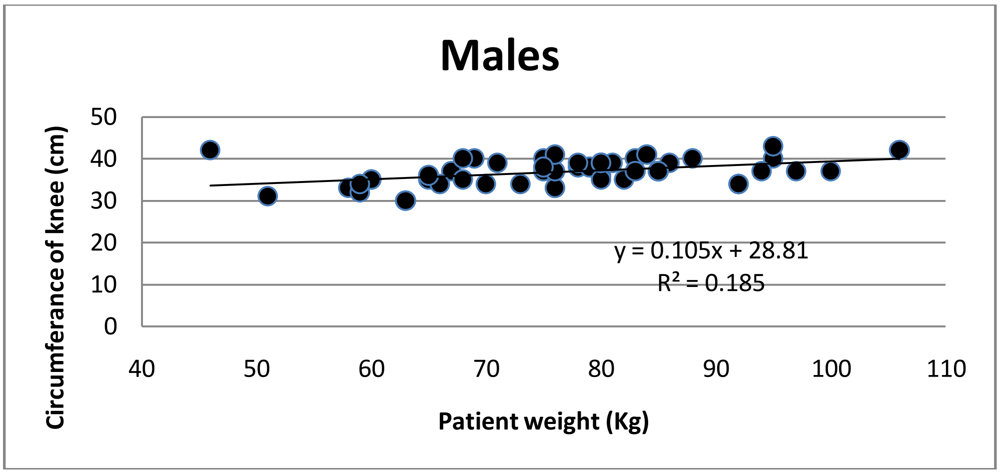
(A)



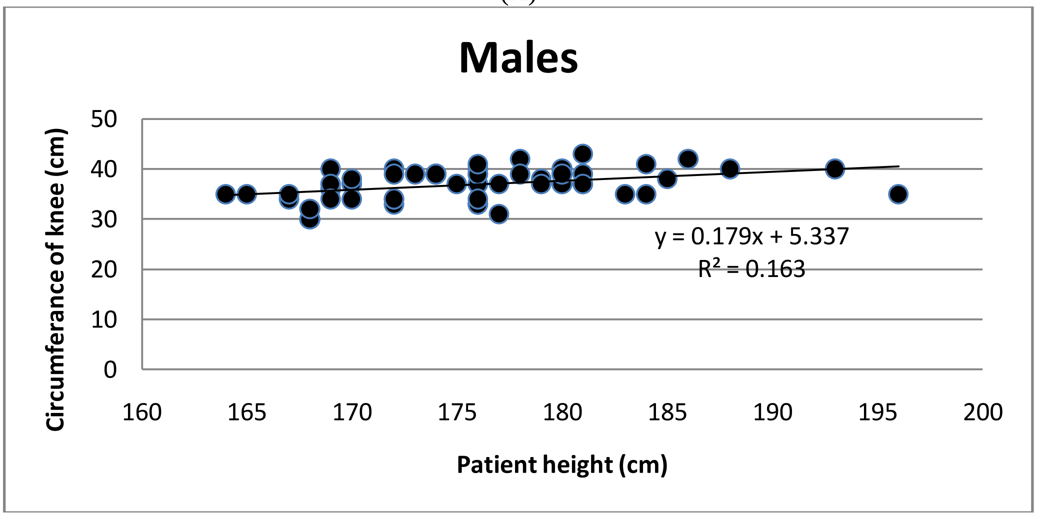
(B)

Fig. 1: scatter plot showed a direct linear relationship of the knee height and patient height for male in (A) and female (B)

Similarly the circumference of the knee was significantly associated with the patient height and weight together for male and female separately. Where the knee circumference increases by 0.11 cm/Kg of patient weight and by 0.18cm/cm of patient height for male as shown in Fig. 2: A & B.



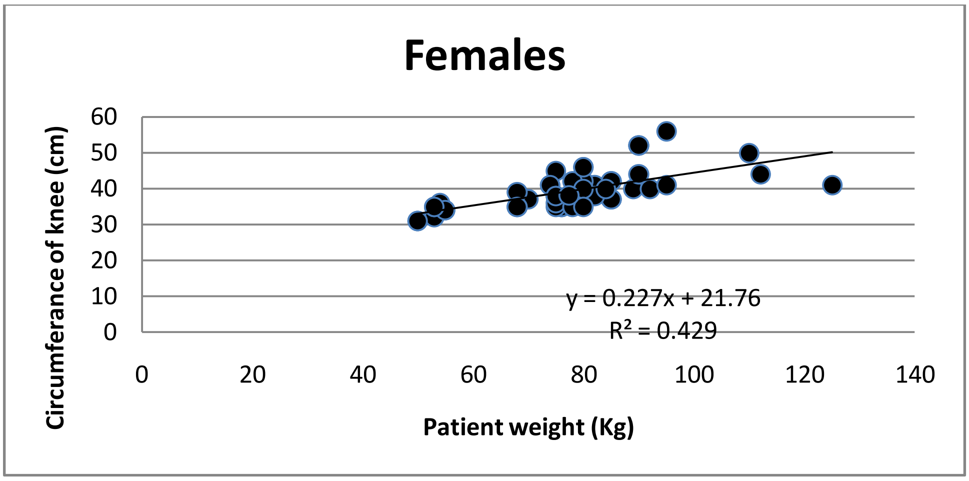
(A)



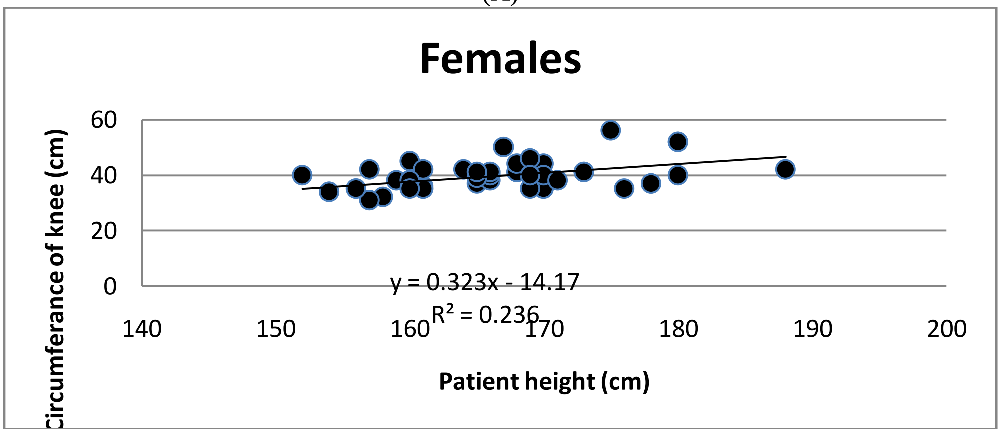
(B)

Fig. 2: scatter plot showed a direct linear relationship of the knee circumference for males and patient weight in (A) and height (B)

For female the knee circufrence in respect to patient weight increase by 0.23 cm/Kg of body weight while for height it increases by 0.32 cm/cm of height. This result also dictate that; circumferance of knee for female is more than that of male. This increase represented by the increase in the coeffecient in cerase of weight and height (Fig. 3: A & B)



(A)



(B)

Fig. 3: scatter plot show a direct linear relationship of the knee circumference for females and patient weight in (A) and height (B)

In this study researchers compared the height and circumference of the knee in symptom patients 'but with a normal X-ray finding' with those suffering from knee joint diseases 'remarkable change in the x-ray film'. The knee circumference showed a significant difference between the two groups while the knee height showed inconclusive result (Table 3). This means disease affect the circumference due to fluid effusion or swelling of the knee area. Also Andrew *et al*. published a manuscript regarding association between and knee height measurements and knee joint structure in an asymptomatic cohort, they revealed that in asymptomatic community-based adults, increased bone area is associated with increased measures of knee height, also found that increased knee height measurements were associated with increased knee cartilage volume and a reduced risk for medial knee cartilage defects. The associations with bone area may simply reflect the association of inherently larger bony structures. However the beneficial associations demonstrated with cartilage morphology suggest that an increased knee height may confer a beneficial biomechanical environment to the chondrocyte of asymptomatic adults [7]. This study is limited; it did not expose to type of disease or categorized the measurement according to disease.

Table 3: A significant *t*-test between the normal knee in x-ray and abnormal one concerning the height and circumference of the knee

Variable	*t*	*p*
Height of Rt. Knee & Height of Lt. knee	1.841	.067
Circumference of Rt. knee & Circumference of Lt. knee	3.692	.000

The status of the symptomatic knee joint weather it show pathology in x-ray or not were significantly correlated with the age of the patient, period of disease and body mass. The coefficient of these associations can be used in a multiple regression equation to predict the presence or absence of the disease prior x-ray examination as follows: knee state = (Age×0.009) + (period of disease×0.003) + (BMI×0.015)

CONCLUSION

This study found that the height and circumference of the knee of male and female were significantly different. The height of the knee significantly associated with the height of the patients, where this height can be estimated for male and female using these equations: Knee height = (0.39 × patient height) - 10.6 and Knee joint = (0.29 × patient height) + 6.7 for male and female respectively. The circumference of the male and female were associated with the height and weight of patients as follows: Knee circumference = (weight × 0.08) + (height×0.13) + 7.7 and Knee circumference = (weight × 0.19) + (height×0.16) - 2.1 for male and female respectively.

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Original Research Article

CHARACTERIZATION OF KNEE JOINT CHANGES IN SUDANESE USING PLAIN X-RAY

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Abstract:
The aim of this study was to characterize knee joints changes in Sudanese population using plain x-ray, in order to comprehend the potential pathological changes that might appears in the plain x-ray film also to calculate bone size for artificial knee joint before surgery. A total of 257 symptomatic knee joints were enrolled in this study,106 showed no change in the x-ray film 'normal', (56 male and 50 female), 151 showed change of knee joint in the plain x-ray (55 males and 96 females).Their age range from18 to 78 years. In this study also study found that the mediolateral femur measurements for male is equal to 6.4 ±1.03 and 5.9± 0.7 for female and the mediolateral tibia measurements is equal to 6.8 ± 0.9 for male and 6.3 ± 0.6 for female. These differences were significant at p=0.05 using the t-test with t=2.62 for male and t=3.07 for female and p=0.04 and 0.02 respectively. The mediolateral femur and tibia measurement were significantly correlated with the height and circumference of the knee, as well these measurements were correlated significantly with the artificial femur and tibia size. Also this study found that the diagnosis = [(TL2X×0.86) + (FL1X×-0.29) + (TW3X×0.63) + (TL1X×0.38)] – 5.85. To identifies the normal for symptomatic cases where the result =1, the patient were normal otherwise patient were affected.

Key words: Characterization of knee joint, Circumference of knee joint and BMI.

Introduction

Annually there were over 500,000 total knee replacement procedures performed in the US. It is projected that by 2030, the volume of this procedure will increase to over 3.48 million per year due to the aging baby-boomers, increased obesity and indications for total knee replacement that extend to both younger as well as older patients.1 From 2000 to 2006, the Medicare total knee replacement rate overall in the United States increased by 58%, from 5.5 to 8.7 per 1,000.2 [1]. The circumference of the knees and thighs at three locations was measured

in 10 patients on two consecutive occasions by three observers. Analysis of the results for interobserver, intraobserver and among-patient variation established that a change in circumference noted by different observers on two different days is significant if it exceeds 1-5 cm at the midpatella, 2-7 cm at 7 cm above, and 3-5 cm at 15 cm above the patella. If a single observer performs both measurements, the change need exceed only 1-0, 2-0, and 2-7 cm, respectively, to be significant [2].
Also in Sudan there were not enough data published locally or internationally regarding the knee joint measurement or knee correlated with gender or even occupation.
The main objective of the current study was 1- To predict the bone measurement using the height and circumference of the knee joint. 2- To find the significant difference between male and female. 3- And to diagnose patient as normal or abnormal. 4- To choose the knee size before the surgeries.

Materials and methods

A total number of 257 patients, 111 (43.19 %) were male and 146 (56.81%) were female; their knee joints X-ray were measured. A bout 106 normal patients (56 male and 50 female) with age ranged between (18-65) years. Bio-data such as height, weight, body mass index and different heights and circumferences of knees were recorded. Also 151 diseased patients with age range between (20-78) years. (55) Were males with percentage (36.42 %) and (96) were females with percentage (63.58 %), were examined using plain x-ray of knee joints as standard group of the same age group.
The data will be presented by using frequency distribution tables which showed the variables then analysis of them by Microsoft EXCEL and statistical package for social science SPSS version 16 under windows. The study was carried in Khartoum state –Sudan in the period from June/2012 to September/2014 in the Modern Medical Centre and Antalya Medical Centre. Also all measurements and imaging performance were carried by the same staff and researchers to prevent enter-expert factor affecting results.
To predict the artificial knee size before surgery researchers were collected all patients that have an artificial knee joint in Sharg Elneel Hospital, Khartoum, Sudan, that was done**,** in the period from August/2014 to October/2014, three months. The artificial knee joint were made of Co Cr Mo alloy for the femur and tibia material and UHMWPE as an insert material. Both female and male patients were (63), **24** male, (15 Rt. Knee and 9 Lt. Knee), and **39** female, (20 Rt. Knee and 19 Lt. Knee) with different ages.

Results and discussion

The results of this study revealed that; there is a difference between male and female body mass index (BMI) although their weight show minor variation Table 1. Also in respect to height and circumference of knee there were no remarkable differences between Rt. and Lt. Knee for normal patient. These results match the result of Badria et al (8).

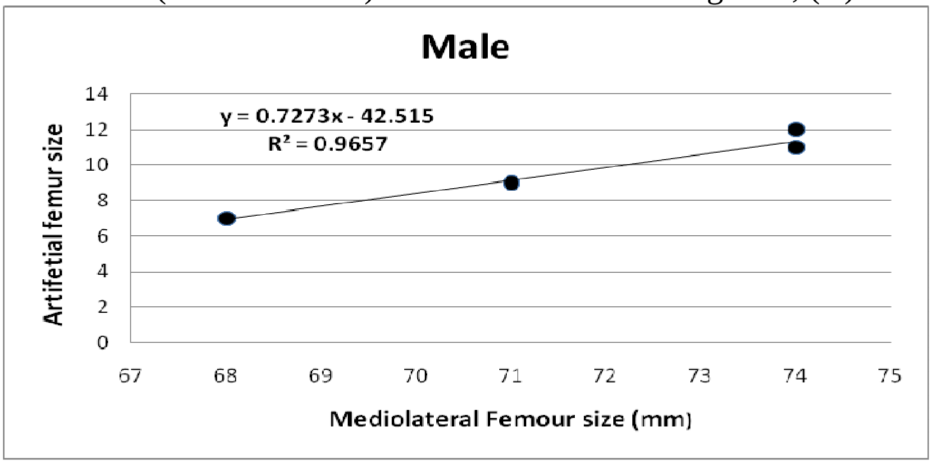
Table (1) the mean ± standard deviation of patient age, weight, height, body mass index and knee joint dimension (Rt. & Lt.) for male and female)

Variables	Male Mean ± SD	Female Mean ± SD
Age	39.2 ± 12.3	42.5 ± 10.1
Height of the Patient	175.6 ± 6.8	166.0 ± 8.0
Weight of the Patient	76.8 ± 12.3	78.1 ± 15.4
BMI	24.9 ± 3.7	28.3 ± 5.1
Height of the Rt. Knee	57.5 ± 3.6	54.2 ± 3.9

Height of the Lt. Knee	57.5 ± 3.6	54.1 ± 3.9
Circumference of the Rt. Knee	36.9 ± 3.0	39.5 ± 5.3
Circumference of the Rt. Knee	36.8 ± 3.1	39.3 ± 5.3

The artificial femur size (AFS) for male increases by 0.73 unit/1 mm of mediolateral femur size MLFS), where the artificial size can be predicted using the following equation:

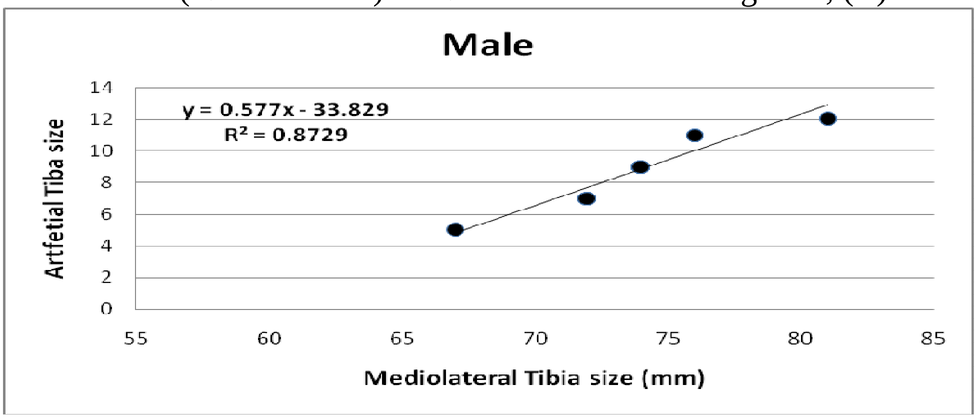
AFS= (0.7273xMLFS) - 42.515as seen in the figure 1, (A).



(A)

The artificial tibia size (ATS) for male increase by 0.58unit/1 mm of mediolateral tibia size (MLTS), where the artificial size can be predicted using the following equation:

ATS= (0.577xMLTS) - 33.829 as seen in the figure 1, (B)

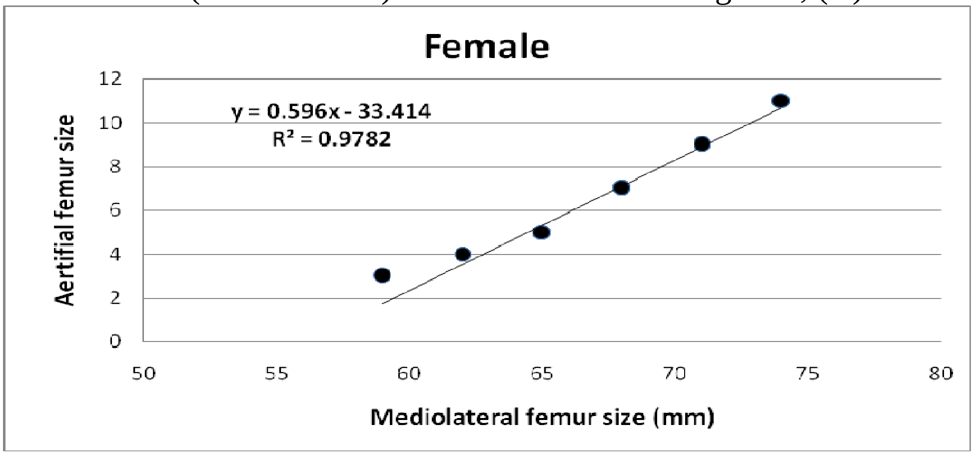


(B)

Figure 1: scatter plot show a direct linear relationship of the mediolateral femur and tibia size with the artificial knee for male.

The artificial femur size (AFS) for male increases by 0.60 unit/1 mm of mediolateral femur size MLFS), where the artificial size can be predicted using the following equation:

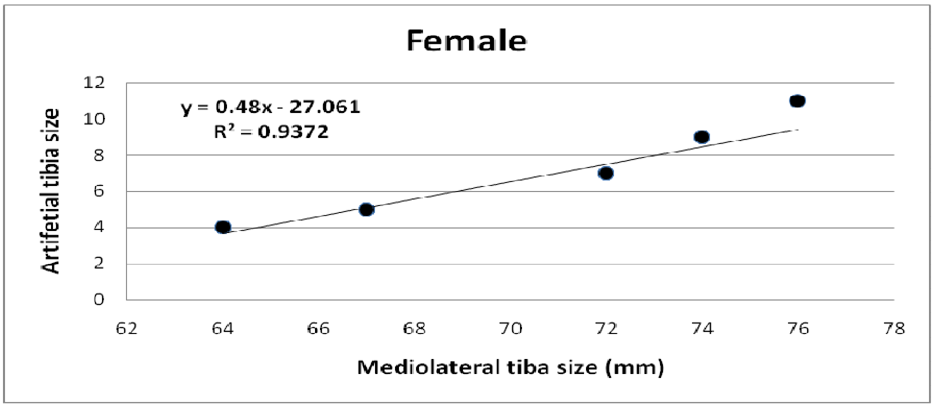
AFS= (0.596xMLFS) -33.414as seen in the figure 2, (A).



(A)

The artificial tibia size (ATS) for male increase by 0.48unit/1 mm of mediolateral tibia size (MLTS), where the artificial size can be predicted using the following equation:

ATS= (0.48xMLTS)-27.061 as seen in the figure 2, (B)



(B)

Figure 2: scatter plot show a direct linear relationship of the mediolateral femur and tibia size with the artificial knee for female.

Conclusion

This study found that **the diagnosis** = (TL2X×0.86) + (FL1X×-0.294) + (TW3X×0.625) + (TL1X×0.383) – 5. 846. Diagnosis= 1 normal knee, 2 abnormal knees.

In this study also study found that the mediolateral femur measurements for male is equal to 6.4 ±1.03 and 5.9± 0.7 for female and the mediolateral tibia measurements is equal to 6.8 ± 0.9 for male and 6.3 ± 0.6 for female. These differences were significant at p=0.05 using the t-test with t=2.62 for male and t=3.07 for female and p=0.04 and 0.02 respectively. The mediolateral femur and tibia measurement were significantly correlated with the height and circumference of the knee, as well these measurements were correlated significantly with the artificial femur and tibia size.

T=Tibia, F=Femur, L=Length, W=Weight and X=X-Rays image.

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