DISSERTATION ON

STUDY OF CORONAL ALIGNMENT OF KNEE AFTER TOTAL KNEE REPLACEMENT

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DECLARATION

I declare that this dissertation entitled **"STUDY OF CORONAL ALIGNMENT OF KNEE AFTER TOTAL KNEE REPLACEMENT''** has been conducted by me at the Department of Orthopaedic Surgery, Kilpauk Medical College & Hospital, Chennai, under the guidance and supervision of my respected Chief **Prof. K. Sankaralingam, D. Ortho, M.S.(Ortho), DNB Ortho,** Government Kilpauk Medical College and Hospital, Chennai. It is submitted in part of fulfillment of the award of the degree of M. S. (Ortho) for the March 2007 examination to be held under The Tamilnadu Dr. M. G. R. Medical University, Chennai. This has not been submitted previously by me for the award of any degree or diploma from any other university**.**

(Dr. S. S. SUKUMARAN)

CERTIFICATE

Certified that the dissertation on "**STUDY OF CORONAL ALIGNMENT OF KNEE AFTER TOTAL KNEE REPLACEMENT**" is a bonafide work done by Dr.S.S.Sukumaran, Postgraduate, Department of Orthopaedic Surgery, Kilpauk Medical College & Hospital, Chennai-10, under my guidance and supervision in partial fulfillment of the regulations of **The Tamilnadu Dr. M. G. R. Medical University** for the award of **M.S. Degree Branch II (Orthopaedic Surgery)** during the academic period of June 2005– March 2007.

Prof. K. Sankaralingam,
D.Ortho. M.S. (Ortho),DNB (Ortho)
Additional Professor of Orthopaedics
Kilpauk Medical College & Hospital
Chennai – 600 010

Prof. A. Sivakumar,
D.Ortho. M.S(Ortho)
Professor and Head
Dept. of Orthopaedics
Kilpauk Medical College
& Hospital
Chennai – 600 010

Prof. Dr. Thiyagavalli Kirubakaran
Dean
Government Kilpauk Medical College
Chennai – 600 010.

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CONTENTS

The surgeon performing a total knee arthroplasty is not only concerned with the early pain relief to the arthritic patient but should also provide the patient with stable functional knee with the maximum implant survival.

Survivorship for cemented total knee arthroplasty ranges between 91% and 99% at ten years and between 91% and 96% at 15 years. [1, 2]

Various factors contribute to the decrease in the longevity of the implants which may be patient specific, material specific, design specific, surgeon specific and biologic specific.

Patient specific factors include age, activity level, bone quality, body mass index and co-morbid conditions.

Material specific factors include component constraint, implant material and design, composition of polyethylene.

Surgeon specific factors include various technical factors like cementation, component alignment, ligament balancing, flexion-extension gap equality and thickness of polyethylene.

Biological factors include osteolysis, wear debris, trace metals, dissemination of metal debris and cellular materials to this debris.

Of these various factor, mal-alignment of the components and hence the axial alignment of limb is well within the control of the operating surgeon.

Several studies have concluded that durability of the total knee replacement is dependent on the postoperative axial alignment of the lower extremity.[13,14,15,16,47,56]

If replacement of the knee leaves the extremity in varus or valgus mal-alignment, loosening and instability occurs at a greater rate than if the limb is well aligned by arthroplasty. Mal-alignment leads to overload of the bone and ligaments, leading to asymmetric bone loss, prosthetic wear and fracture and ligamentous instability.

Preoperative axial alignment of the lower extremity is essential to assess the bony cuts to be taken during surgery as well as the ligamentous balancing to be performed intra operatively.

Hence assessment of axial alignment before and after surgery is imperative in any patient undergoing a knee replacement surgery.

Best method of assessing axial alignment is to assess the mechanical axis of the lower extremity in the coronal plane.

The normal standing radiograph which provides a view of the knee only, is prone to errors of parallax and poor control of patient positioning.[46] Weight bearing full length radiograph of the lower limb including the hip, knee and ankle is essential for the accurate assessment of mechanical axis and hence the axial alignment of the lower extremity.

The aim of the study is to compare the axial alignment of the lower extremity before and after surgery in patients undergoing total knee replacement by assessing the mechanical axis in the full length weight bearing radiograph taken preoperatively and post operatively.

As early as 1861, Fergusson reported performing a resection arthroplasty of the knee for arthritis.[3] Verneuil generally is credited with performing the first interposition arthroplasty of the knee in 1863, when he inserted a flap of joint capsule between the two resected joint surfaces to prevent them from growing together.[4] Many other substances were subsequently tried by various surgeons as interposition material including skin, muscle, fat and even chromatized pig bladder.

In the 1920s and 1930s, Campbell popularized the use of free fascial grafts as an interposition material. [5]

Following Smith-Petersen's success with mold arthroplasty of the hip, mold hemiarthroplasty of the knee was attempted by Campbell and Boyd in 1940 and by Smith-Petersen in 1942.[6,7]

Tibial hemiarthroplasty also was attempted in the McKeever and MacIntosh tibial plateau prostheses.[8]

The first attempts to replace both femoral and tibial articular surfaces appeared in the 1950s as hinged implants with intramedullary stems developed by Walldius, Shiers, and others.[9]

In 1971, Gunston reported his early results with the Polycentric knee, in which he incorporated many of the concepts of Charnley's low friction arthroplasty of the hip.[10]

He also recognized that the knee does not rotate on a single axis like a hinge, but rather the femoral condyles roll and glide on the tibia with multiple instant centers of rotation. This concept has become known as femoral roll-back.

The Total Condylar prosthesis was designed by Insall and others at the Hospital for Special Surgery in 1973. This prosthesis followed the philosophy that mechanical considerations should outweigh the desire to anatomically reproduce the kinematics of normal knee motion.

The concept of the weight bearing or "mechanical" axis was described by **Pauwels** in his classic work “Biomechanics of the locomotor apparatus” published in 1980.[11] He has described mechanical axis as a static weight bearing axis which can be drawn on a radiographic image of the limb.

Earlier in 1972, Maquet has described the axial alignment of the lower limb and the mechanical axis is some time described as “Maquet Line”[12]

Various studies published in different periods have proved that a strong relationship exists between the post-operative mechanical axis and the long term survival of the implants. [13,14,15,16]

In early 1977 Lotke et al in their work on the “influence of positioning of prosthesis in total knee replacement” has noted a significant positive correlation between a good clinical result and a well positioned prosthesis.[13]

They believe that the long-term clinical results, wear resistance and resistance to prosthetic failure depend on correct positioning of the devices.

Weinstein et al in 1986, quantitatively evaluated the relationship between component placement, limb alignment, and function following unicompartmental knee replacement surgery.[14] It was found that anatomic alignment, prosthetic positioning, and prosthetic design influence the patients' ability to walk and climb stairs.

In 1987, Kennedy et al have analyzed the relationship between the postoperative mechanical axis and the overall clinical results.[15] One hundred consecutive medial compartment knee arthroplasties for osteoarthritis were followed for an average period of 51 months.

Superior results were obtained when the mechanical axis fell in the center of the knee or slightly medial to the center

Component mal-positioning seems to be a fundamental cause for failure, in knee arthroplasty. On analysis of 87 semi constrained knee prosthesis, Jonsson et al in 1988 conclude that total alignment between 6 degrees of varus and 7 degrees of valgus was associated with good clinical results.[16]

In a bone model study conducted in Department of Orthopedic Surgery, Harvard Medical School, Boston in 1989, Hsu et al have concluded that misalignment by 5 degrees yielded a 40% change in the load distribution; a 10 degrees misalignment produced changes of 62% [17]

Robert Jeffery et al in 1991 have reported a series of 115 knees, with an average follow-up of 12 years. The incidence of loosening was only 3% when the mechanical axis was in the centre and it increased to a significant level of 24% when the axis was medial or lateral.

In a review of 421 cases of knee replacement Ritter et al in 1994 have concluded that the surgeon should align the prosthesis in neutral or slight amount of valgus to give the patient the best chance of long term survival.[18]

Kolstad et al in 1996 have concluded that a post operative valgus angle of the leg of 3 degrees or more tended to increase the risk of revision.[19]

When compared to standard intramedullary and extramedullary referencing systems, computer-assisted navigation systems have been shown in multiple randomized studies to increase the accuracy of bone resections in total knee arthroplasty. Accuracy to within 1 degrees in the coronal plane resections can routinely be obtained.

Hufner et al have made the observation that with the help of navigation, it is possible to achieve a higher degree of precision in total hip and knee implant placement, including a distinct reduction in variance as compared to conventional techniques.[21]

Fehring et al in a study of 18 cases whom they believed could not be operated using traditional instruments, were able to achieve the mechanical axis in 17 knees perfectly.[22] They conclude that computer-assisted navigation seemed helpful in difficult situations where accurate alignment remains crucial, yet traditional instrumentation is not applicable.

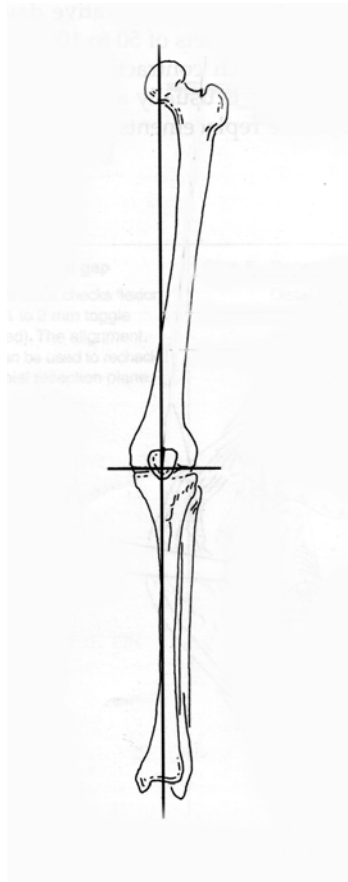
Mechanical Axes

The concept of the weight bearing or "mechanical" axis was described by **Pauwels** in 1980.[11] It is a static weight bearing axis which can be drawn on a radiographic image of the limb. The ground reaction force line is a dynamic equivalent of the mechanical axis and can be "visualized" using instrumented gait analysis.

The mechanical axis of the lower limb in the frontal plane is defined as a line drawn from the centre of the femoral head to the centre of the ankle joint. This line is also called as **Maquet's line.**[12] It normally passes through the centre of the knee joint in the frontal plane, described as 'neutral mechanical axis'.

The distance of this line from the centre of the knee on a long-leg radiograph provides the most accurate measure of coronal alignment. Mal alignment causes abnormal forces which may lead to loosening after knee replacement.

During normal gait the mechanical axis is inclined 3 degrees from the vertical axis of the body, with feet closer to the midline than the hips.



In the sagittal plane the normal mechanical axis runs from the centre of gravity (in front of S2), to the centre of the ankle joint. It therefore runs just behind the femoral head because the femoral neck is anteverted about 15degrees) and just in front of the knee.

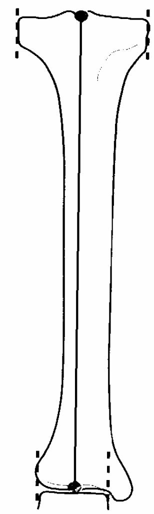
When the mechanical axis lies to the lateral side of the knee center, the knee is in mechanical valgus alignment. In mechanical varus alignment, the axis lies to the medial side of the knee center.

Segmental Mechanical Axes

Each long bone has a mechanical axis and an anatomic axis. [52,53,54,55] The mechanical axis of a long bone is defined as the straight line connecting the joint centre points of the proximal and distal joints. The anatomical axis of a bone is the mid diaphyseal line. The mechanical axis is always a straight line whether in the frontal or in the sagittal plane.The anatomic axis may be straight in the frontal plane but curved in the sagittal plane as in the femur. In tibia the anatomic axis is straight both in the frontal plane as well as in the sagittal plane. Axis lines are applicable to any longitudinal projection of a bone.Here we refer only to the frontal plane axis which corresponds to the AP radiographic projection.

Tibial axes

In tibia the frontal plane mechanical and anatomical axes are parallel and only a few millimeter apart. Hence for all practical purposes, its mechanical axis is the same as its anatomical axis and runs from the centre of the knee to the centre of the ankle.



Mechanical axis

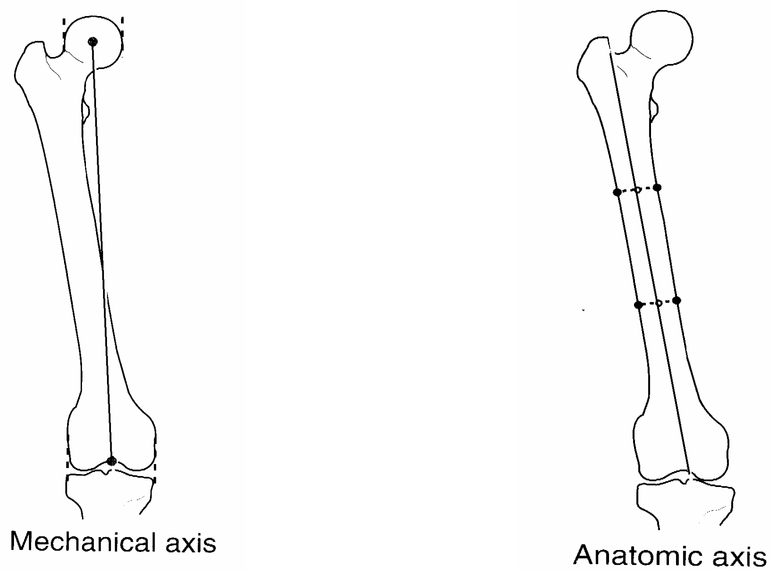
Femoral axes

In the femur the anatomical and mechanical axes are not parallel. They converge distally.

The mechanical axis of femur runs from the centre of femoral head to centre of knee.

The anatomical axis of the femur intersects the knee joint line medial to the knee joint centre in the vicinity of medial tibial spine.

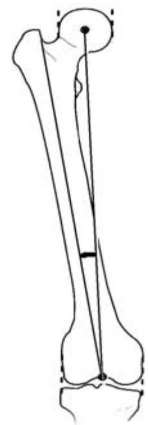
When extended proximally it usually passes through the piriform fossa just medial to the greater trochanter medial cortex.



Physiologic valgus angle (Alpha angle)

The anatomical axis of femur is in 6 degrees of valgus from the mechanical axis of lower limb and 9 degrees of valgus from the true vertical axis of the body. This angle which is formed between the anatomical and mechanical axes of the femur is the physiological valgus angle or the alpha angle.

This angle has an important bearing in the distal cut of the femur during the intra operative procedure. It decides the angle at which the intra-medullary alignment rod is to be fixed to the femoral cutting block.



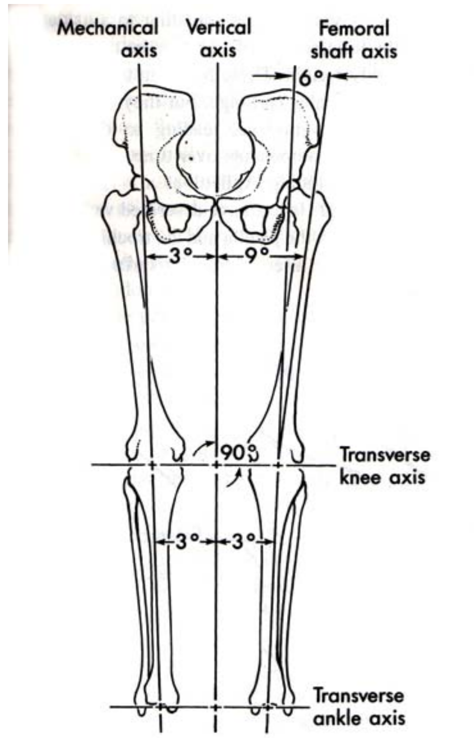
Alpha Angle

Joint alignment refers to the co-linearity of the hip, knee and ankle. Alignment is determined by the mechanical axis passing from the centre of the femoral head to the ankle. Mal-alignment in the leg is defined by deviation of the centre of the knee from this line.[24]

Joint orientation refers to the relationship of the joint surface to the axis of the long bone. Aline can also represent the orientation of the joint in a particular plane or projection. This is called the joint orientation line.

Ankle

Ankle joint orientation line is drawn across the flat subchondral line of the tibial plafond in either the distal tibial suchondral line or for the subchondral line of the dome of the talus.



Knee

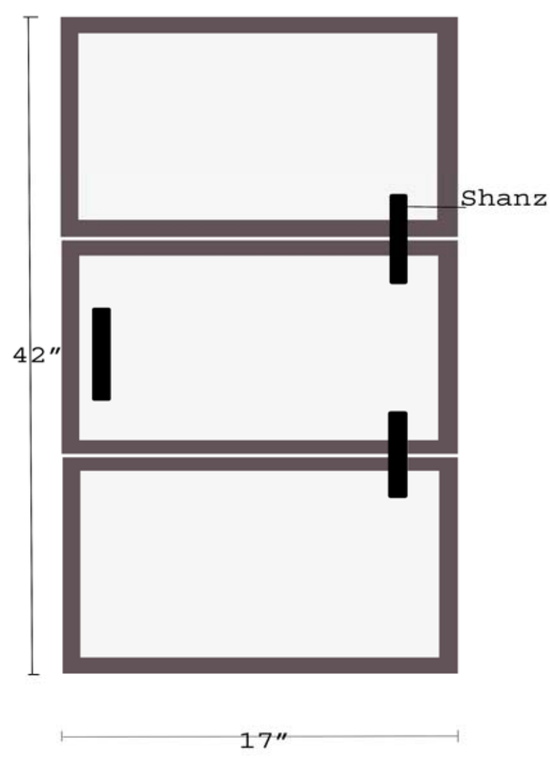
The frontal plane knee joint line of the proximal tibia is drawn across the flat or concave aspect of the subchondral line of the two tibial plateaus. The frontal plane knee joint orientation line of the distal femur is drawn as a line tangential to the most distal points on the convexity of the two femoral condyles.

Hip

A line drawn from the proximal tip of the greater trochanter to the centre of the femoral head represents the joint orientation line in the frontal plane.

Cassette frame

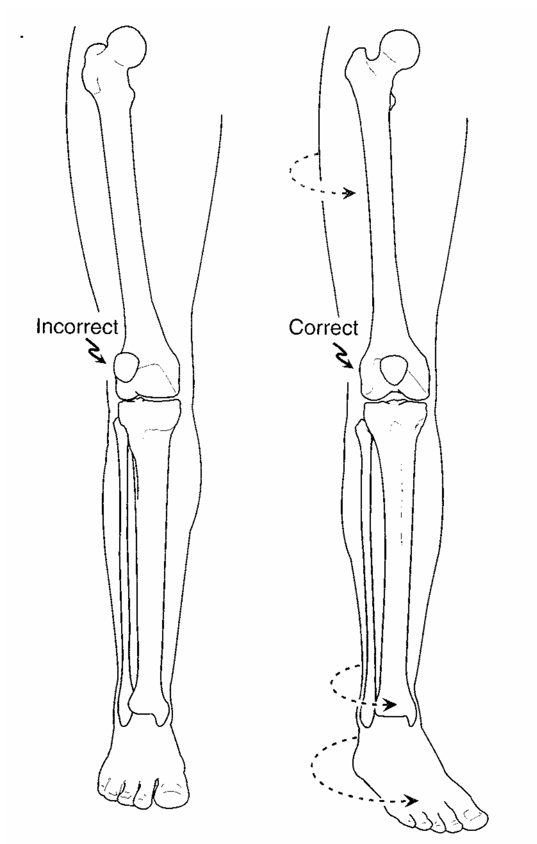
Three 14” X 17” cassettes are stacked together and mounted on a wooden frame.[24] Two metal markers usually 4.5mmX 150mm Shanz pins are pasted at the junction of the metal edges of the cassettes in a vertical direction. Third Shanz of similar dimension is placed in the middle of the centre cassette



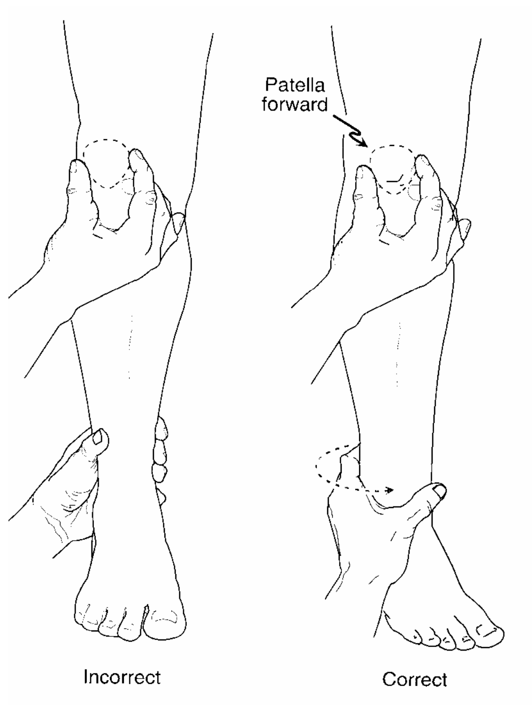
Total height of the cassette is 42 inches and the width is 17 inches.

Patient Positioning

Patient is made to stand in front of wooden frame mounted with the cassette. He/She is instructed to bear weight on both feet equally. For standing radiographs, the radiography technologists are usually taught to position the patient with the feet together. But if the patient has external or internal tibial torsion, such positioning will result in the patella pointing inward or outward. This will result in wrong interpretation of mechanical axes.[25]

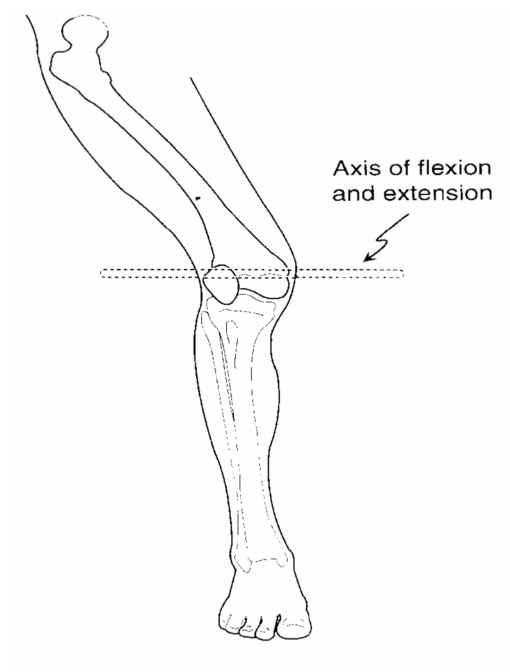


The correct method is to orient the patella forward, irrespective of the foot position. To orient the patella forward, the patella is felt with the index finger and the thumb of one hand and rotated forward till it points forward. The radiograph confirms the correct position, showing the patella centered between femoral condyles.[24]



Another method to assess the orientation of the limb is based on flexion extension axis of the knee without considering the position of the patella.[24]

The limb is positioned so that the X-ray beam is perpendicular to the flexion-extension axis of the knee. The knee joint axis is parallel to the cassette.

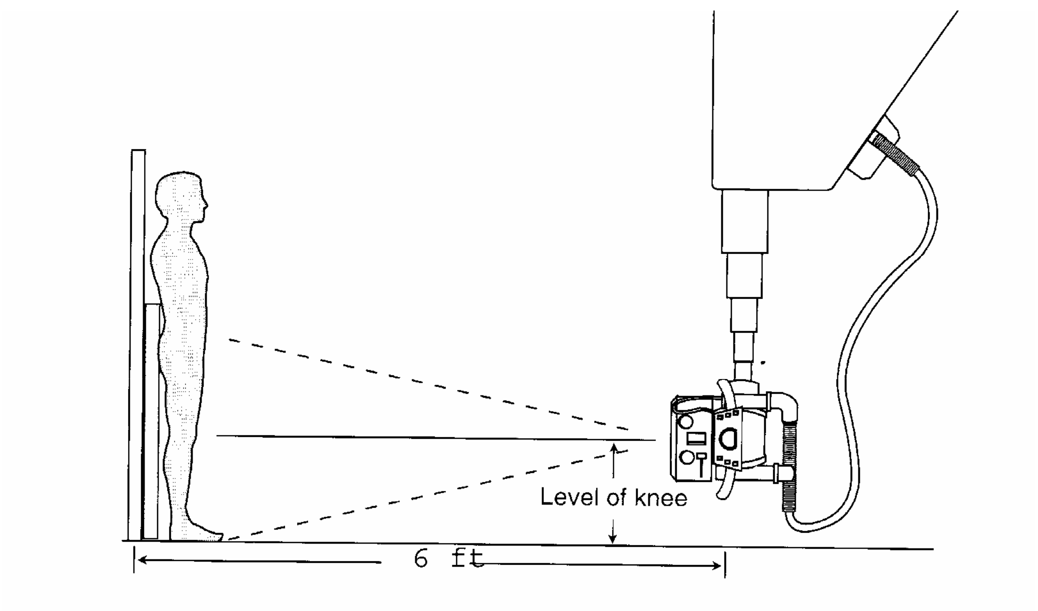


The plane of the knee flexion extension axis is approximately 3 degrees externally rotated to the frontal plane. However a difference less than 5 degrees does not alter the joint orientation lines significantly. Wright et al in their experiment on the impact of rotation on alignment radiograph have stated that 20 degree of either rotation produced only a small overall effect on the alignment radiograph.[25]

Therefore whether the radiograph is obtained in the true frontal plane or perpendicular the knee flexion axis, the angles measured will be approximately the same.

Exposure

The radiograph is taken by digital X-ray. The X-ray source is placed at a distance of 6 feet from the patient. The beam is centered on the knee joint of the patient. The patient is asked to bear weight equally on both the legs. Any rotation if present is corrected.



A 100 mA, 0.05 second exposure is used at 100 to 115 kV, ending on the leg thickness. The approximate magnification by this method is 10% - 20%.

Digitization of radiographs

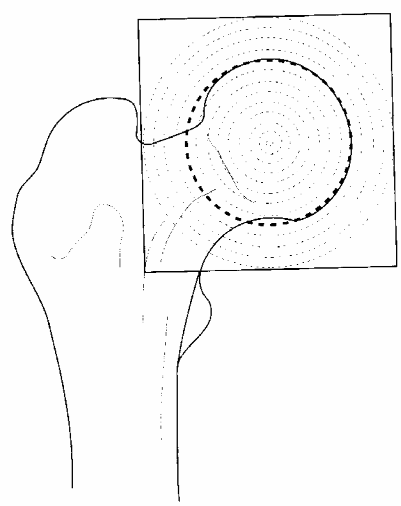
Captured image is transferred to a computer and the image is processed in the Scandock image software. Correct magnification factor is assessed using the shanz pin placed in the centre of central cassette. With the magnification factor thus obtained, the image from the three cassettes are stitched and aligned using the two shanz pin placed across the junction of the cassettes.

Finally the mechanical axis of the lower extremity, anatomical and mechanical axes of the femur as well as the tibia are made. The tibial plateau is divided into seven zones and the zone through which the mechanical axis passes is determined. Final print out is made from the computer in a 14”to17” x-ray film.

As already discussed the mechanical axis passes through joint centre points. Because the mechanical axis is considered mostly in the frontal plane, we need to define only the frontal plane joint centre points of the hip, knee and ankle.

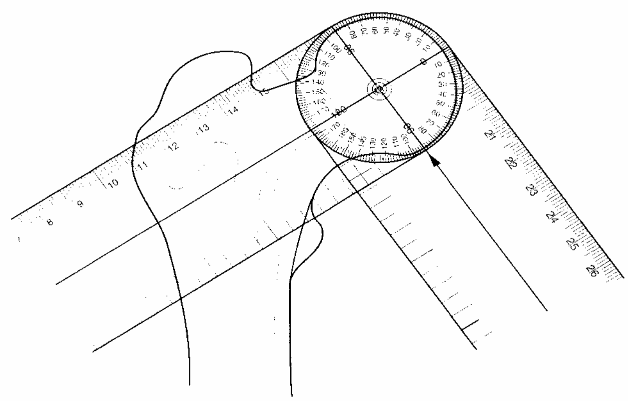
Hip Joint centre point

Moreland et al studied the joint centre points of the hip, knee and ankle.[26]



For hip joint, the joint centre point was the centre of the circular femoral head. The centre of the femoral head was identified by using Moses circles. If these were unavailable, the longitudinal diameter of the femoral head was measured and divided in to two. This distance was used to measure from the medial edge of the femoral head.

For all practical purposes the circular part of the goniometer was used to define this point.[24]



Knee Joint centre point

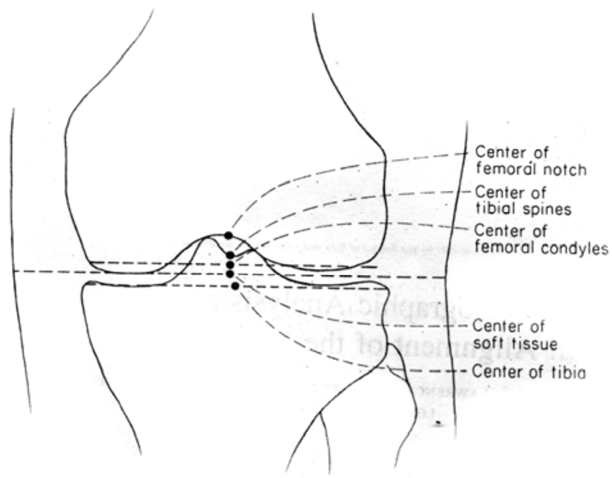
Moreland et al evaluated different geometrical methods to define the centre of the knee joint.

Five centre were determined: [26]

1) Soft tissue centre at the level of the cartilaginous space
2) Centre of the tibia
3) Centre of the femoral condyles at the level of the top of the intercondylar notch
4) Centre of the tips of the tibial spines
5) Centre of the intercondylar notch

All five points were found to be close to each other.

Most medial point was usually the femoral notch and the most lateral point was usually the centre of the tibial plateau. For the centre of the knee, visually selected mid-point of these five points was used



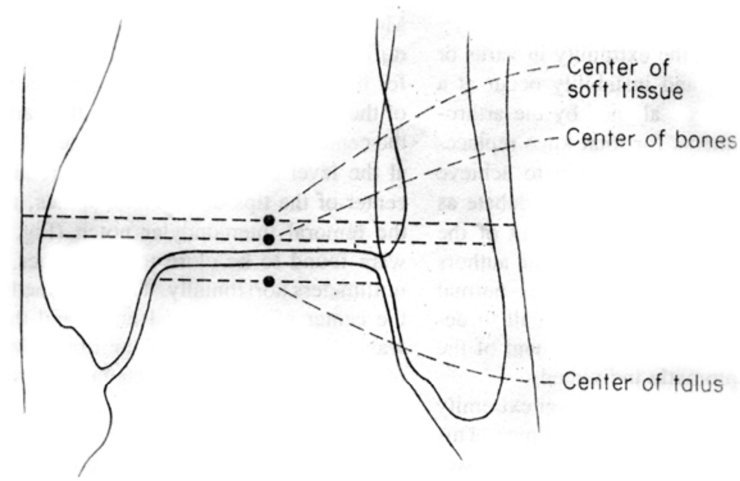
Ankle centre point

The joint centre point of the ankle was visually selected as the mid-point of three measured points: [26]

1) Centre of the soft tissue just proximal to the level of the cartilaginous space

2) Centre of the external surface of the malleoli just proximal to the level of cartilaginous space

3) Centre of the talus



Mechanical Axes

A line was drawn from the centre of the femoral head to the centre of the knee; this line was called the **mechanical axis of the femur.** A second line was drawn from the centre of the knee to the centre of the ankle and this was called the **mechanical axis of the tibia.**

The **mechanical axis of the lower extremity** was taken to be a line drawn between the centre of the femoral head and the centre of the ankle. If the mechanical axis passed through the centre of the knee then the mechanical axes of the femur and tibia were co-linear.

Knee physiologic valgus angle

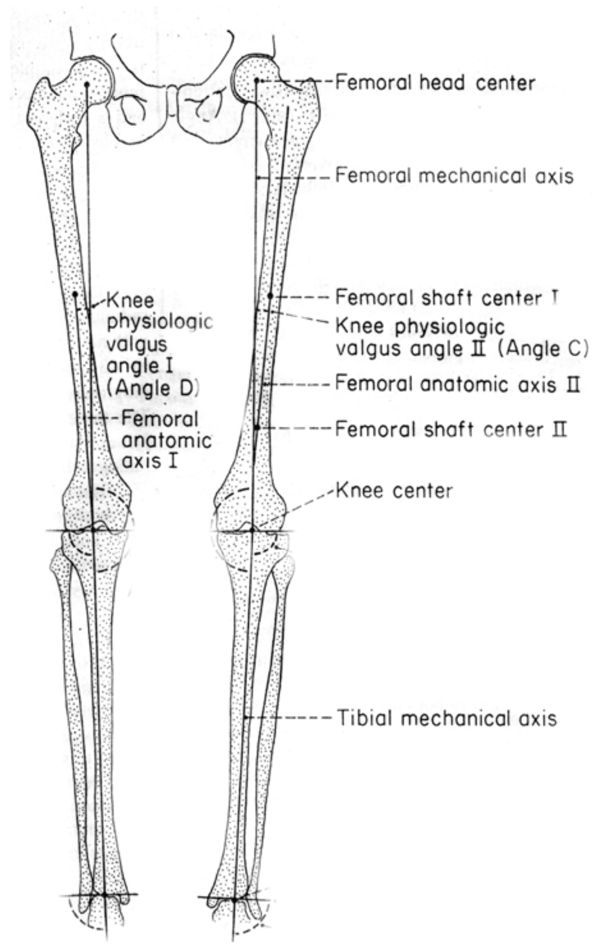
The angle between the anatomic and mechanic axes of femur is called the knee physiologic valgus angle.

As discussed in the preceding paragraph the mechanical axis of femur runs from the centre of the femoral head to the centre of the knee joint.

Two methods of defining the anatomical axis of the femur were used.[26]

First a point named femoral shaft centre I was located by bisecting the proximal to distal length of the femur (as defined by a line from the superior aspect of the femoral head to the distal part of the medial condyle) and the mid shaft medial to lateral width of the femur. A line was drawn from this point to the previously defined centre of the knee and was called femoral anatomical axis I. It was recognized that in the metaphyseal region of the femur this line was not in the centre of the femur but instead usually lay slightly to the lateral side of the femur. A second point named femoral shaft centre II was located 10cms above the surface of the knee joint. A line was then drawn connecting this point with femoral shaft centre I and this line was called femoral anatomical axis II.

This line seemed to be an appropriate representation of the anatomical axis of the femur, since it follows the centre of the femoral shaft more closely.



The angle between the femoral anatomical axis II and its mechanical axis is measured as the knee physiologic angle or alpha angle.

Tibial Zones

Next the tibial plateau was divided into seven zones namely 0, 1, 2, C, 3, 4, 5 where C represents the central zone.[15]

Zone 0 : Medial to the medial end of medial tibial plateau

Zone 1 : Medial half of medial tibial plateau

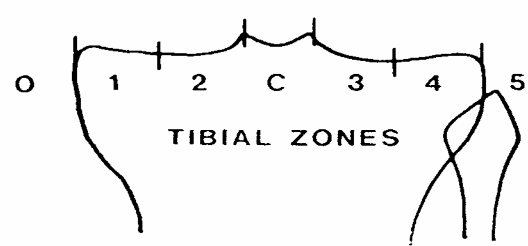
Zone 2 : Lateral half of medial tibial plateau

Zone C : Between tibial spine

Zone 3 : Medial half of lateral tibial plateau

Zone 4 : Lateral half of lateral tibial plateau

Zone 5 : Lateral to the lateral end of lateral tibial plateau



The zone of the knee through which the mechanical axis of the leg passed was then recorded. This recording was made in preoperative as well as postoperative full length radiograph and results analyzed.

Inclusion Criteria

In our hospital total knee arthroplasty is being done for various indications. This includes varus as well as valgus knees.

The period of study is from June 2004 and August 2006. During the study period 18 knees were replaced in12 patients. Of them two patients with three knees lost follow-up.

All patients who underwent total knee arthroplasty in our hospital during the period of June 2004 to August 2006 with regular follow-up are included in this study. This includes 10 patients with 15 knees.

Exclusion Criteria

The patients who did not turn for follow-up were excluded from the study. This included two patients with three knees.

Age Group

Range	47y to 76y
Mean	58.53y
Median	62y

Sex Ratio

Total	10
Male	3
Female	7

Indication

Disease	**Number**
Osteoarthritis	10
Rheumatoid Arthritis	5
Others	Nil

Side

Side	**Number**
Right	3
Left	2
Bilateral	5

Type of Deformity

Deformity	**Number**
Varus	10
Valgus	5

Preoperatively height and weight of the patients are recorded and the Body Mass Index calculated and graded as per the WHO guidelines.[28, 29]

Scoring system formulated by the American Knee Society is used to evaluate the patients before and after surgery. Both knee scores and functional scores are calculated with each amounting to a total of 100 points.[30]

Preoperative full length radiograph was taken in all the patients who underwent knee replacement surgery.

Radiological grading system[31] as advocated by Kellegren and Lawrence was used to evaluate the severity of the arthritis and graded from I to IV as follows:

Grade		Definition
I	Doubtful	Minute osteophyte, doubtful significance
II	Mild	Definite osteophyte, unimpaired joint space
III	Moderate	Moderate diminution of joint space
IV	Severe	Joint space greatly impaired with sclerosis of subchondral bone

The physiologic valgus angle determined after marking the mechanical and anatomical axes of the femur.[26]

Joint centre of the hip knee and ankle were marked. Mechanical axis of the limb to be operated was marked. Deviation from the centre of the knee joint centre was calculated by dividing the tibial plateau into seven zones and determining the zone through which the axis passed.[15]

All the sixteen cases were performed by different surgeons at various period of time during the study period.

Pneumatic tourniquet was routinely used in all cases.

PCL was sacrificed in all the cases.

In 10 cases ultra-congruent tibial inserts were used to prevent dorsal instability.

In 5 cases 'posterior stabilized version is used to overcome the PCL insufficiency. This version includes femoral component that incorporates a box in the area of the intercondylar notch into which a tibial insert with a raised peg engages. The peg's limit stop can compensate for threatened dorsal translation. The cemented standard tibial component is used for the tibia.

Implant Design	Number
Ultra-congruent tibial insert	10
Posterior stabilized version	5

DVT prophylaxis was not given to any of our patient.

Standard postoperative protocol as advised by the American Knee society was followed. Patients were discharged after suture removal on the tenth post operative day.

Postoperative full length radiograph was taken during the first review, four weeks after surgery; the mechanical axis as well the deviation of the mechanical axis was determined as before and values compared with the preoperative measurements and the results analyzed.

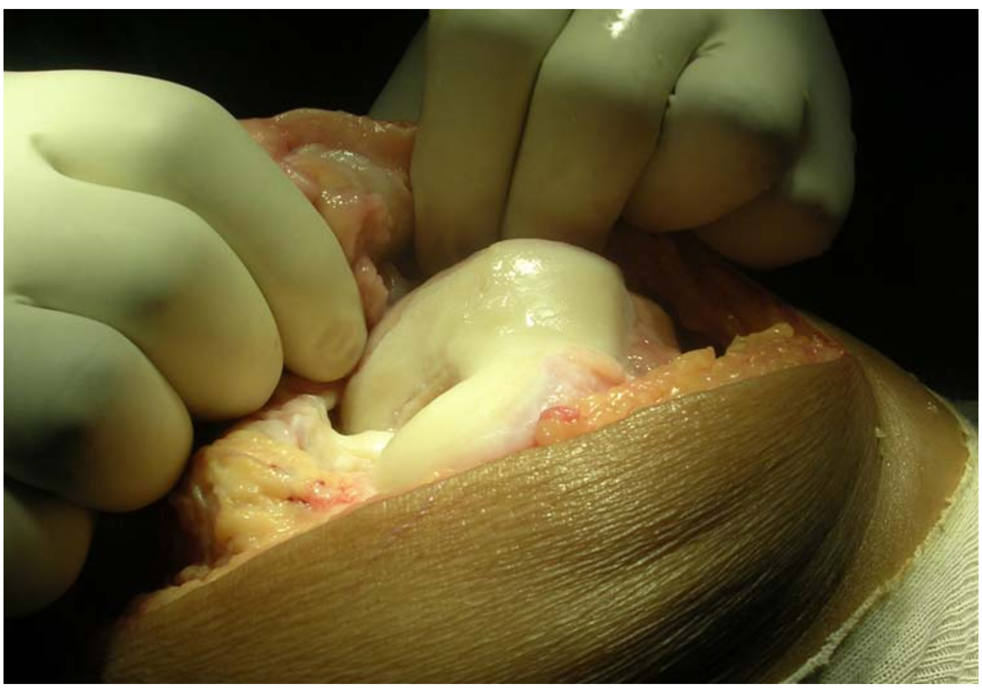
Data from the study analysed by paired'‘t’ test and results critically reviewed.

TOURNIQUET

POSITION

DRAPING

PATELLA EVERTED

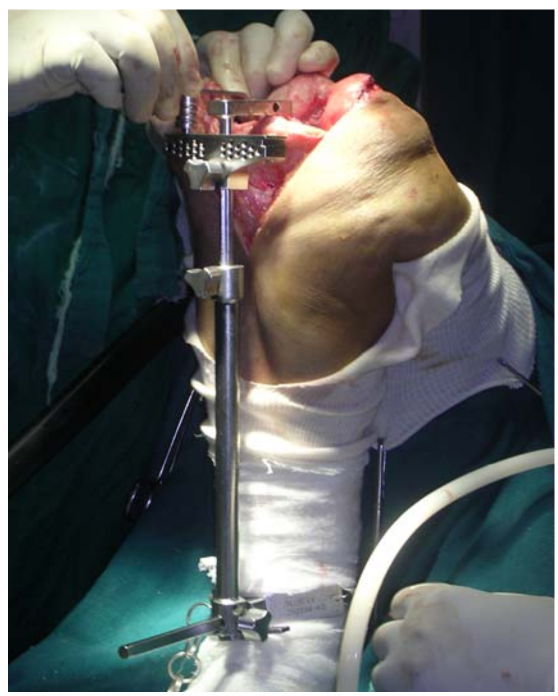


REMOVAL OF MENISCI

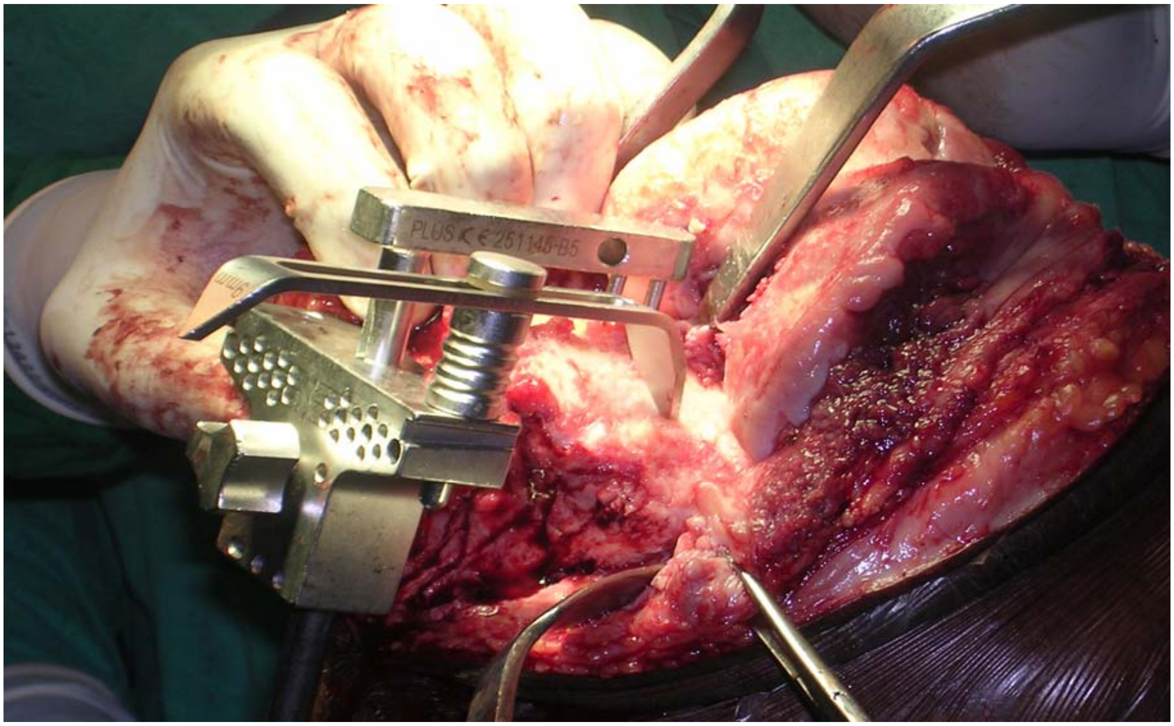
NIBBLING OF OSTEOPHYTE

EXTRAMEDULLARY JIG

STYLUS

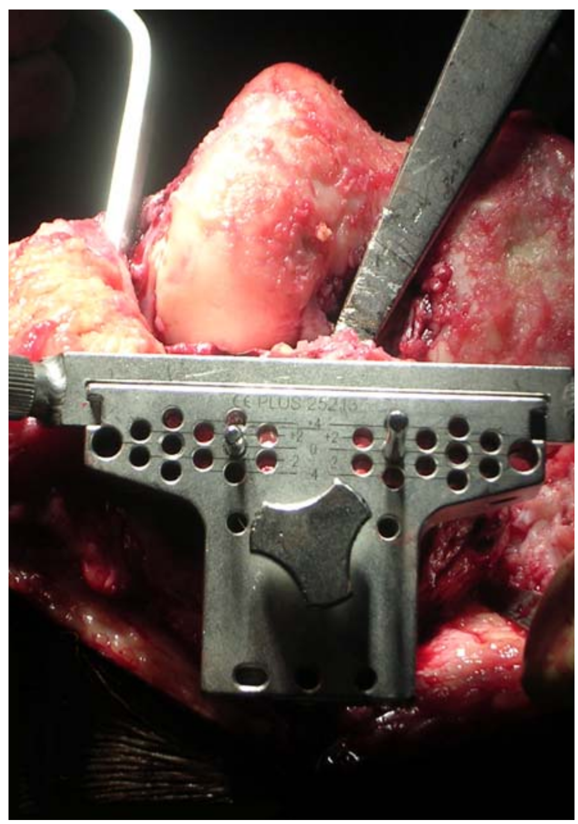


ADJUSTING RESECTION LEVEL



ADJUSTING SLOPE

TIBIAL CUTTING BLOCK

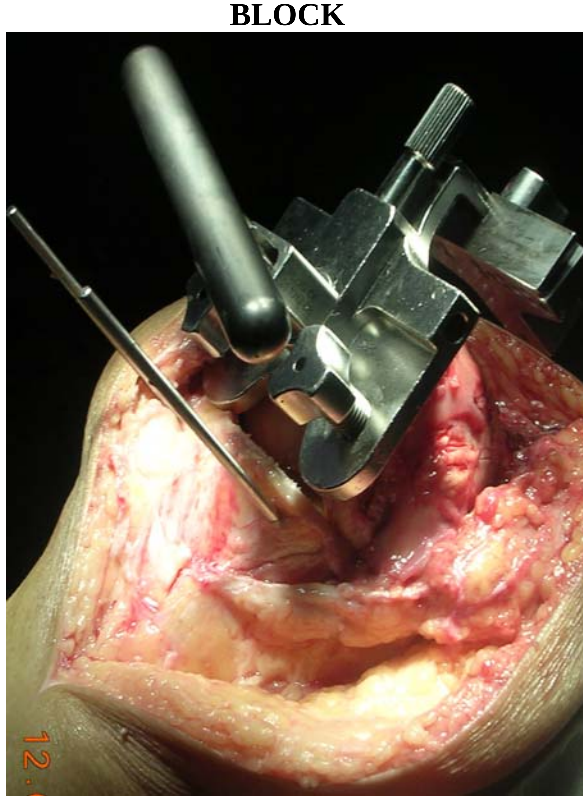


TIBIAL CUT

AFTER THE CUT

FEMORAL DRILLING

DISTAL FEMORAL CUTTING BLOCK



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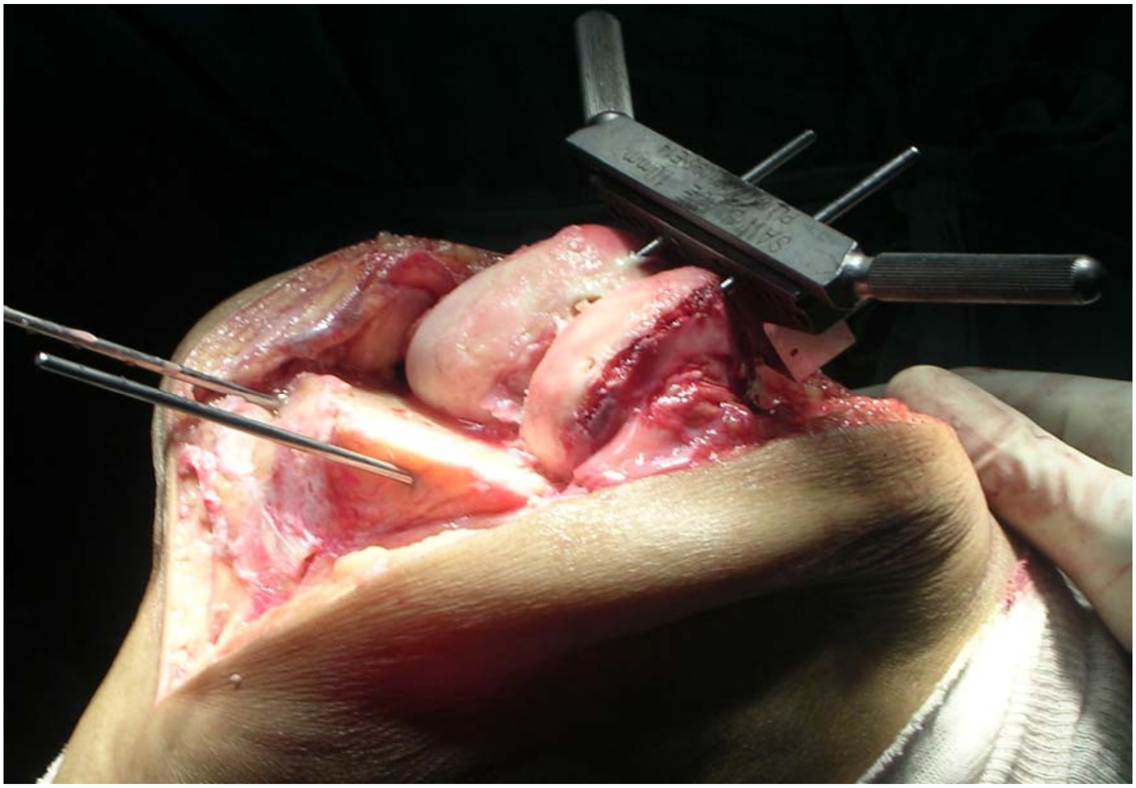
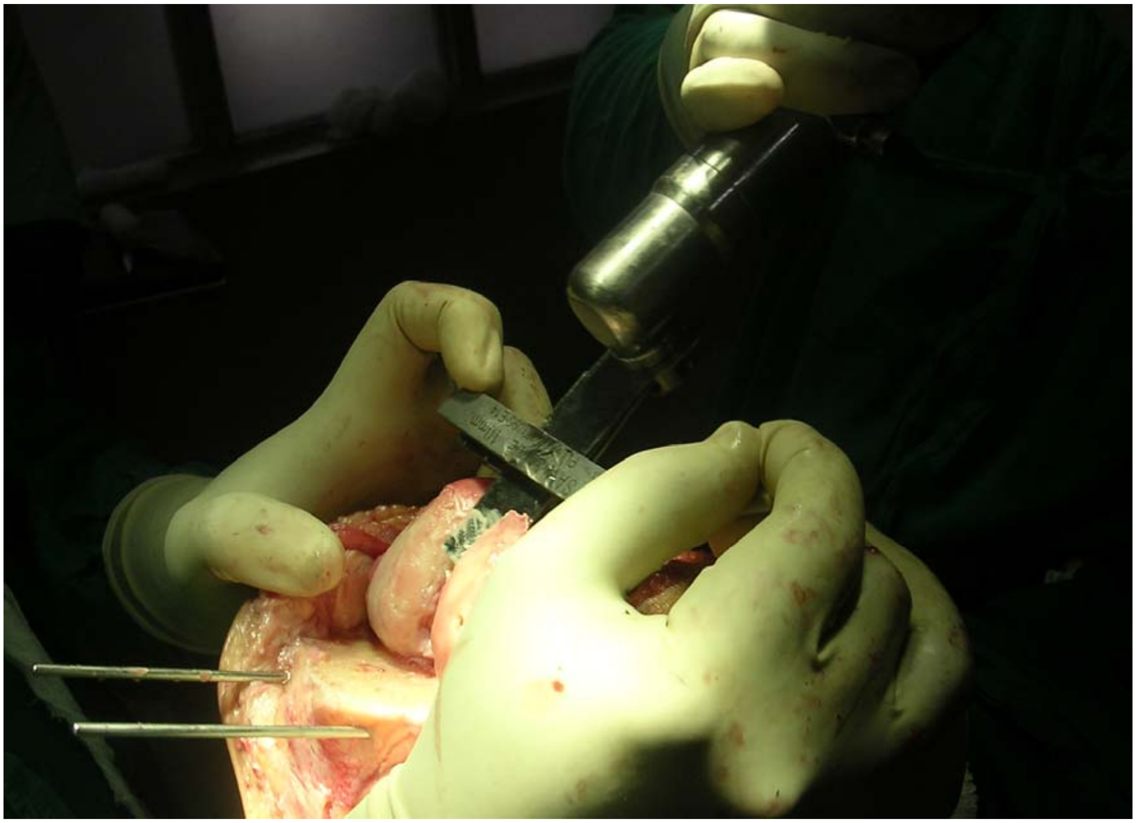


DISTAL CUT



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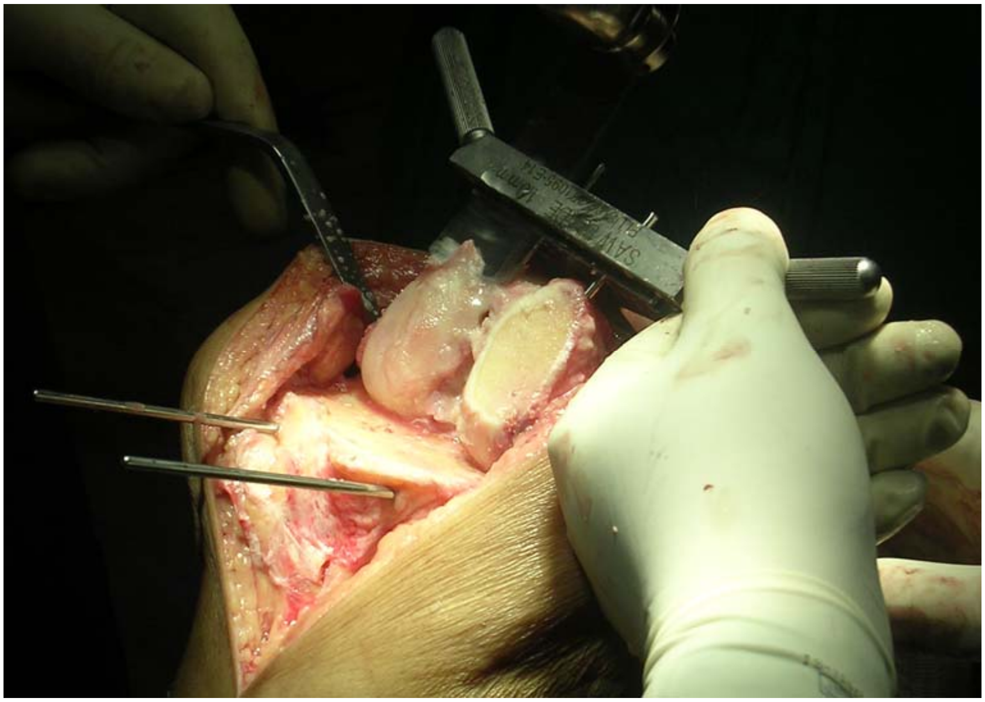
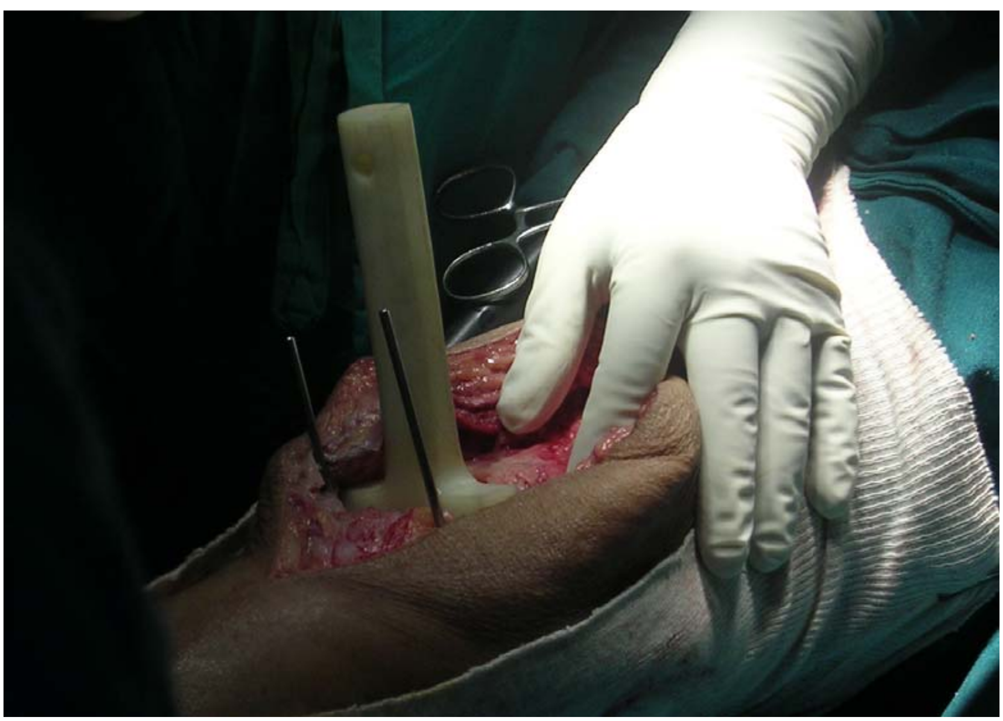


EXTENSION GAP



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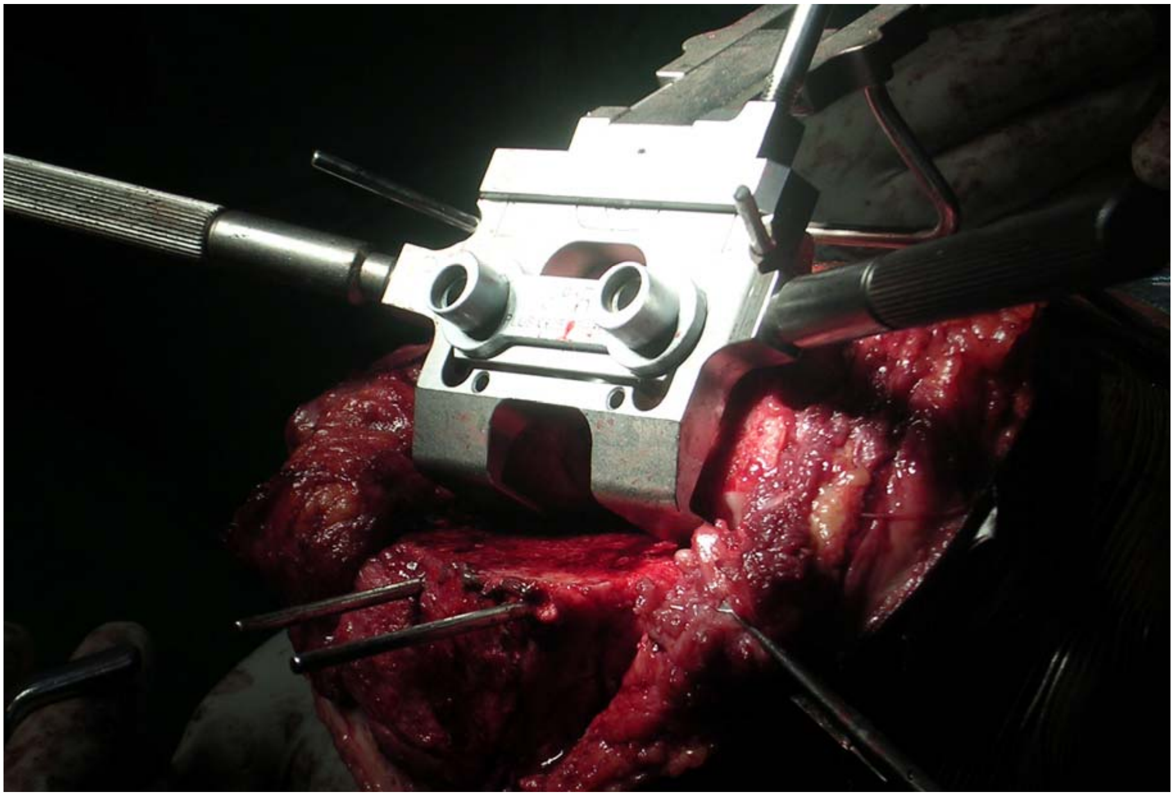
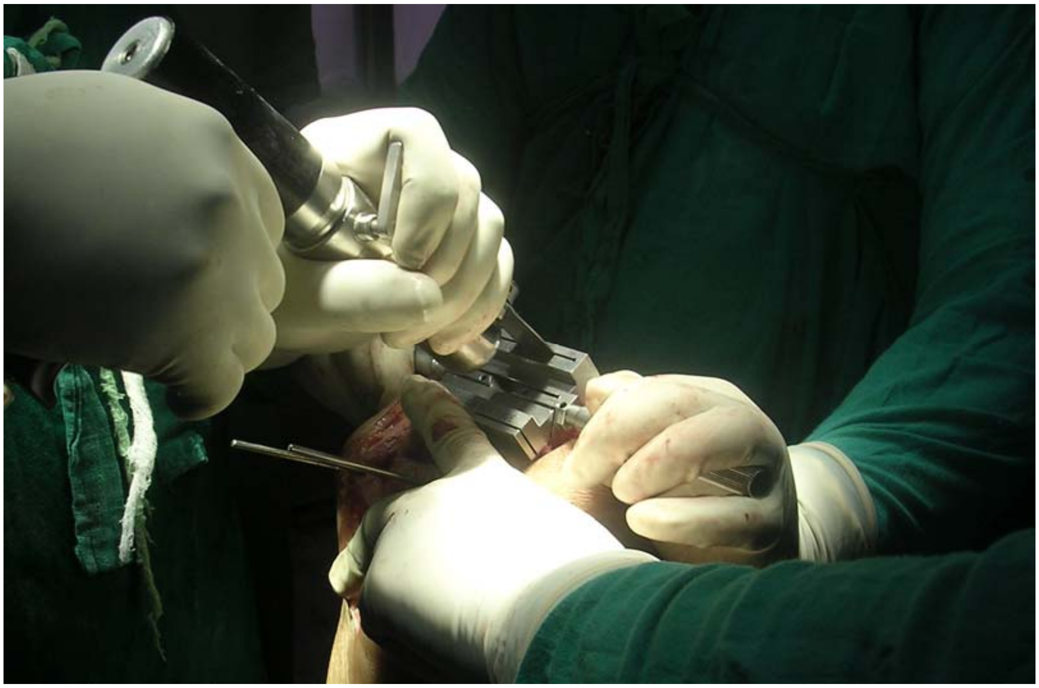
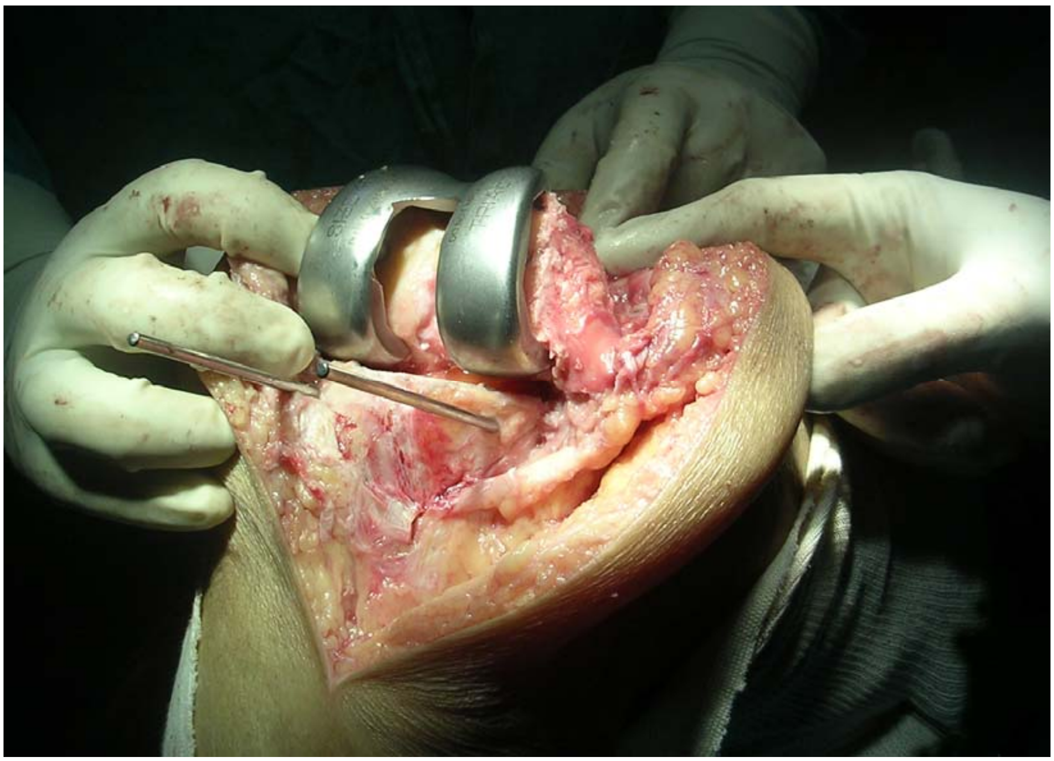


FEMORAL CUTTING BLOCK

FEMORAL CUTS



TRIAL FEMUR



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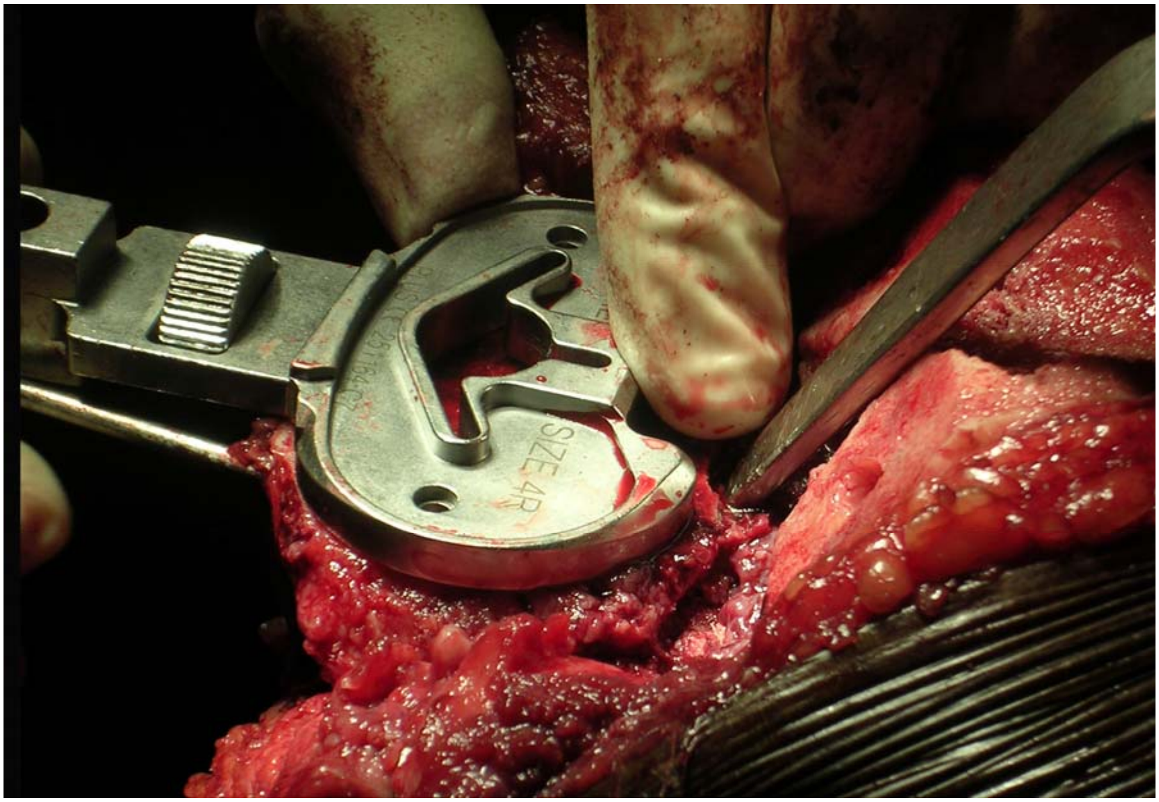
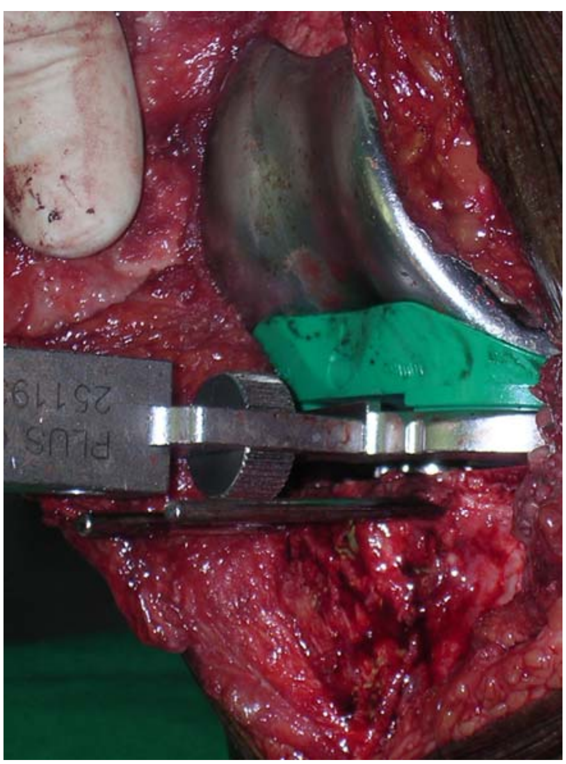
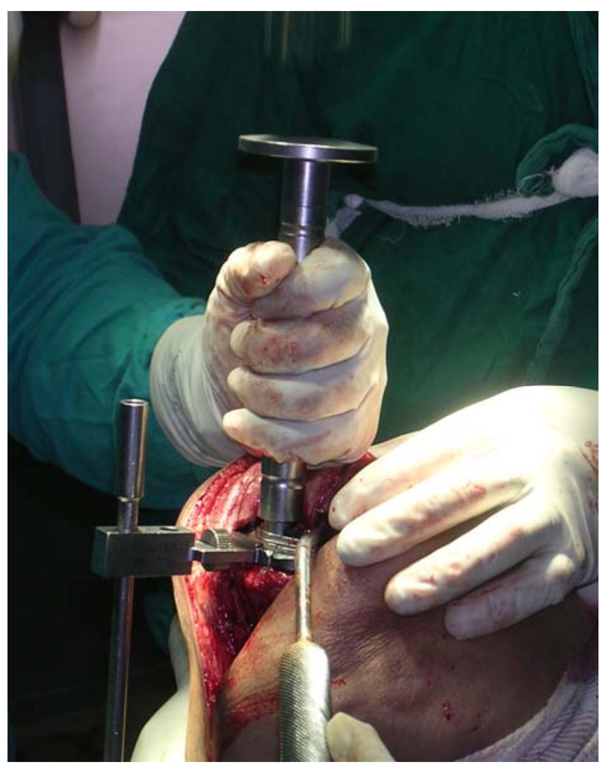


TRIAL FITTING



TIBIAL PREPARATION



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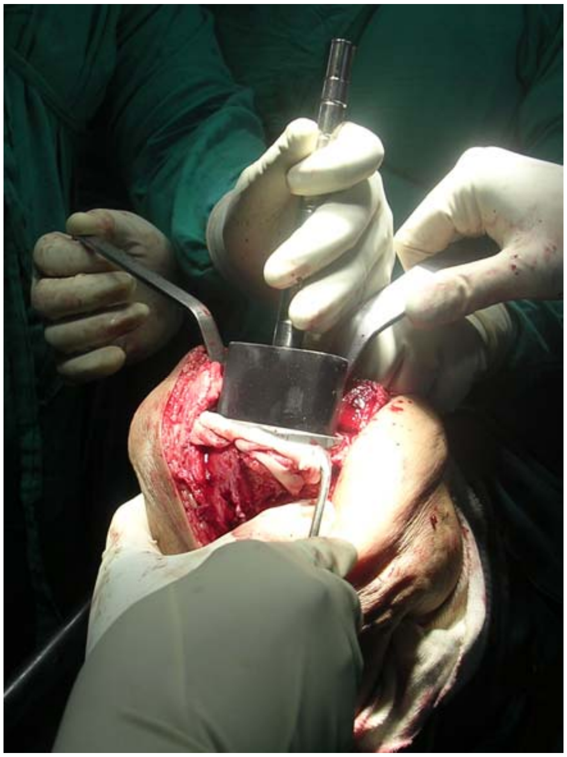

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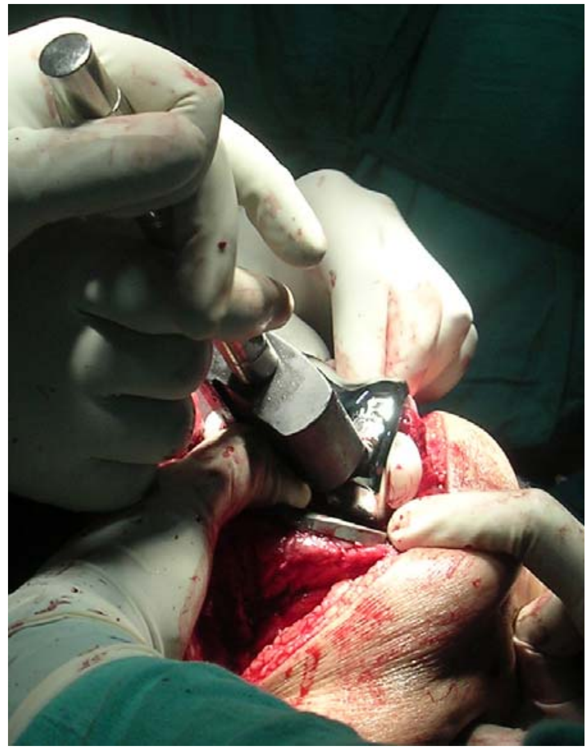
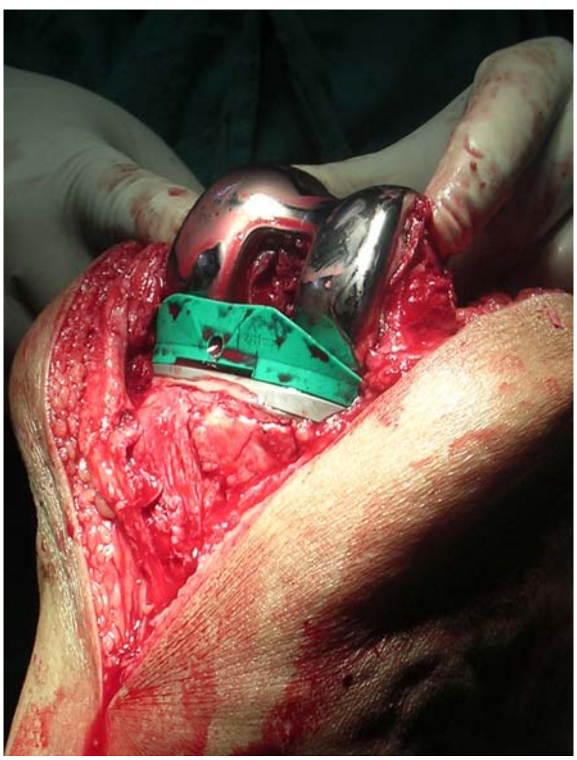
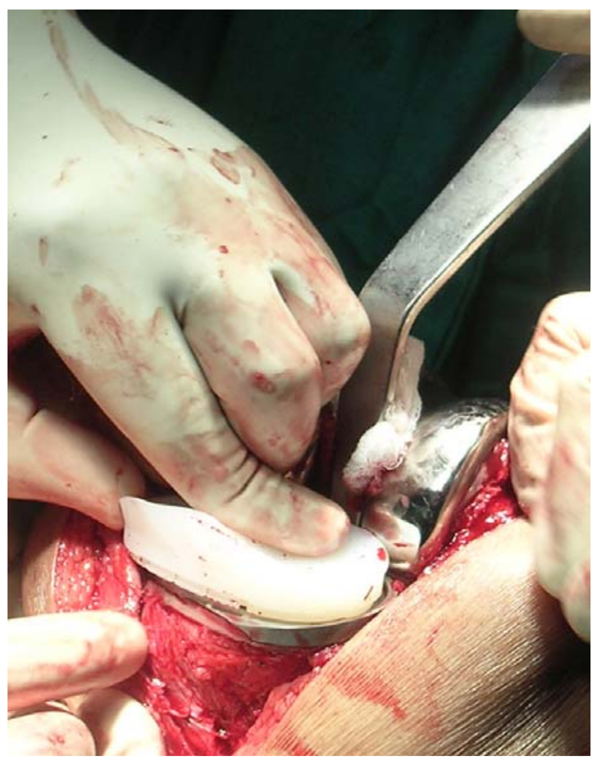


TRIAL POLY

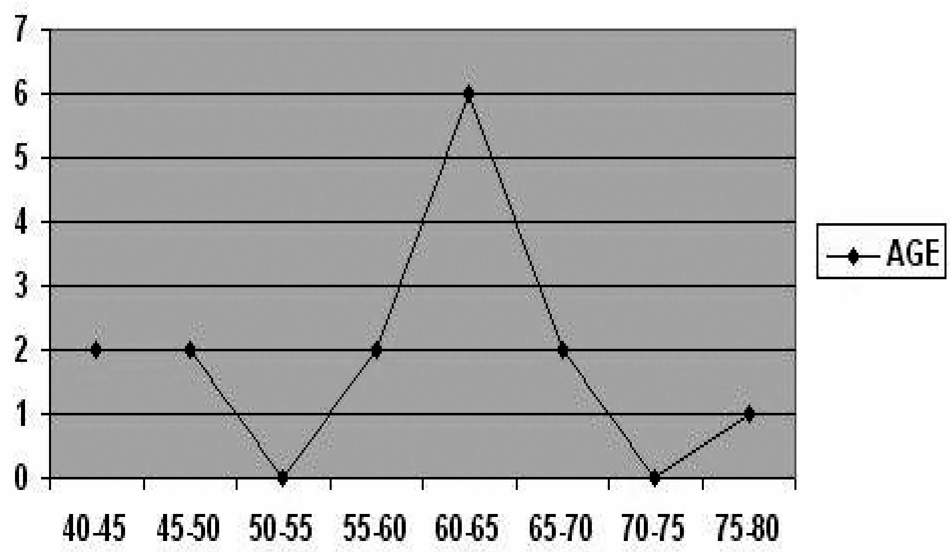


POLY INSERT



Age Distribution

The age of the patients who underwent total knee replacement in our series ranged from 42 to 76 years; average was 58.53 years. The standard deviation was 9.7823 and 53% of our patient belonged to the sixth decade



Height

The range in our series was from 150cms to 165cms. The mean was 155.86cms and the SD was 4.9503

Weight

The range was from 48kgs to 80kgs. The average weight was 58.73kgs and the SD was 8.2415

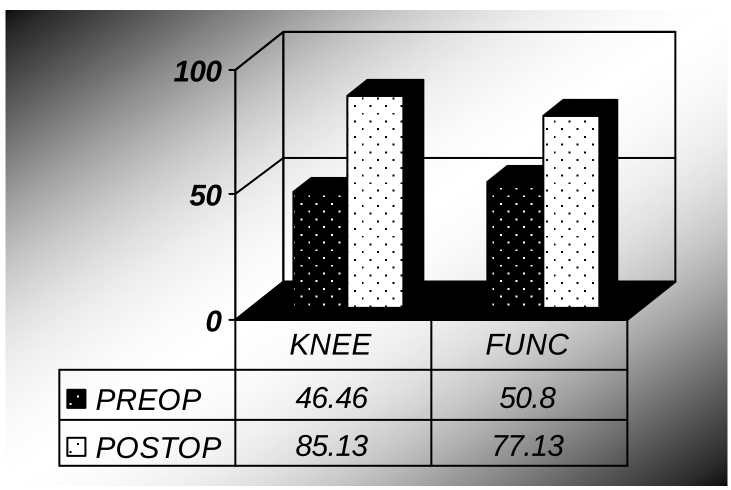
BMI

86% of patients were within the normal range of the BMI. Two patients were categorized as Grade I over weight and one was under Grade II over weight. Mean was 24.212 and SD 3.3864

KSS Score

All the patients were evaluated by scoring system proposed by the The American Knee Society.

The average preoperative KSS score was 46.46 with the range of 38 to 54 and SD of 5.7304 It improved by 41.54 to an average of 85.13 postoperatively, the SD being 11.4820

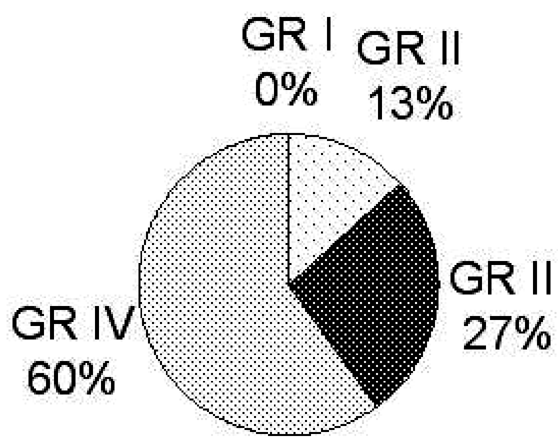


The average preoperative functional score was 50.80 with a range of 44 to 58(SD 3.8582)

It improved postoperatively by a margin of 27.20 to an average of 77.13 (range 50-86and SD 9.4102).

KL Grading

The severity of the arthritis was assessed with the Kellegren and Lawrence scoring system which revealed that 60% (no=9) of our patient had grade IV arthritis at presentation.



Valgus angle

The physiological valgus angle was measured in all our patients using the preoperative full length radiograph. This angle is significant in that it decides the perpendicularity of the femoral cut to the mechanical axis of femur. Of the total number of fifteen 86.67% of our patients had a valgus angle (alpha angle) of 7 degrees.

Mechanical axis

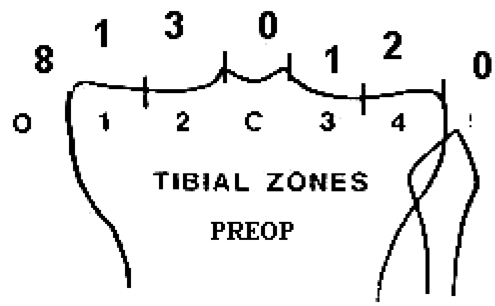
Full length weight bearing radiographs were taken preoperatively as well as postoperatively. Mechanical axes were assessed from the full length radiograph both pre operatively and post operatively as discussed earlier. Critical analysis revealed the following results.

Before surgery mechanical axis passed through the middle third of the knee in none of our patients whereas after surgery in 46.7% of the cases the mechanical axis passed through the centre of the knee (Zone C) and in 40% it passed through the zone 2.

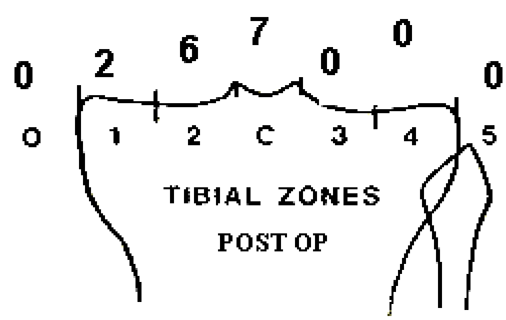
The high number of results with a mechanical axis that passed through zone 2 or zone C indicates the natural tendency of the surgeon to position the knee in a neutral or slightly valgus alignment.

	Zone 0	**Zone 1**	**Zone 2**	**Zone C**	**Zone 3**	**Zone 4**	**Zone 5**
Preop (N=15)	8	1	3	Nil	1	2	Nil
Postop(N=15)	Nil	2	6	7	Nil	Nil	Nil

Zones and no of cases- Preoperative



Zones and no of cases- Postoperative



It was also observed in our study that failure to achieve postoperative axial alignment occurred in one valgus knee and in one varus knee which accounts for about 13% of cases.

Total knee arthroplasty for arthritic patients in whom all the conservative measures are exhausted, is an excellent procedure if proper attention is paid to the patient selection. Meticulous surgical technique must be performed to attain satisfactory postoperative alignment.

Various factors are associated with the onset and progression of clinical osteoarthritis.[32-40] These include genetic factors, age, sex, obesity, occupation, abnormal loading of the joint as in kneeling, squatting and cross legged sitting.

The mean age of our patients who had osteoarthritis is lesser than the data available from the western population. 86% of our patients are well within the normal range of body mass index of <25kg/ square metre.

This significantly differs from the western population where clinical osteoarthritis is associated with increasing BMI. The earlier onset of osteoarthritis in individuals with normal range of BMI is explained by the habit of kneeling, squatting, cross legged sitting practiced by the population in this part of the world. Various studies have confirmed the abnormal loading of knee joint during heavy physical activity, particularly kneeling, squatting and cross legged sitting.[32-40]

Eckstein et al in their study on the in vivo cartilage deformation during different types of activity has noted that the pattern of patellar cartilage deformation corresponded to the range of motion involved in a particular activity.[41]

Sixty percent of our patients had Grade IV osteoarthritis with complete obliteration of joint space at the time of initial presentation.[31] Their presentation at this advanced stage indicates the lack of awareness about the nature of the disease and about the availability of the various treatment modalities including surgery. Low socio-economic status and illiteracy may be a contributing factor for this.

Various scoring system are in vogue to assess the outcome of total knee arthroplasty: Knee injury and Osteoarthritis Outcome Score (KOOS), Western Ontario and McMaster OA index (WOMAC), Oxford 12-item Knee Questionnaire, American knee society score, The Hospital for Special Surgery Rating System.

We have used the scoring system as advocated by the American Knee Society. According to this system only the three main parameters of pain, stability and range of motion should be judged.

Flexion contracture, extension lag and misalignment should be dealt with as deductions. Thus, 100 points will be obtained by a well-aligned knee with no pain, 125 degrees of motion, and negligible anteroposterior and mediolateral instability. Patient function considers only walking distance and stair climbing, with deductions for walking aids. The maximum function score, which is also 100, is obtained by a patient who can walk an unlimited distance and go up and down stairs normally.[30]

All the 15 patients were evaluated both preoperatively and post operatively. Knee score has increased by 41.54 to attain an average of 88 points postoperatively. Comparative analysis by paired‘t’ test reveals a statistically significant p value of 0.00

The functional score has also increased by an average of 27.20 to reach an average of 77.13 postoperatively. Statistical analysis reveal a ‘p’ value which is significant (p=0.000001).

Score	Preoperative		Postoperative		‘p’ value
	Mean	SD	Mean	SD	
Knee score	46.46	5.73045	85.13	11.48208	p=0.00
Functional score	50.80	3.85820	77.13	9.4102	p=0.000001

The results of our study compare favorably with the data available in the literature.

Good functional results are obtained by correctly positioned implants. Proper positioning of the implants is assessed by the central alignment of the mechanical axis.[27] Long radiographs including hip, knee and ankle (three joint x-ray) are essential to study the axial alignments.

Short radiographs and short arm goniometers are accurate only to 5 degrees. When the patient is carefully positioned and the knees are in full extension and the patient is bearing weight in both knees, full length standing radiographs can be used to measure the angles to within 2 degrees. Measuring this angle to 5 degree accuracy would not appear to be sufficiently precise to detect the moderate degree of mal-alignment which can affect the result. [26]

The rotation of the lower extremity will affect the apparent alignment that is seen when the radiograph is made.[49] If the knee is flexed a little, external rotation will make knee appear to be in more varus angulation, and internal rotation will accentuate the degree of valgus angulation. Thus the radiograph should be made with the patella pointing straight ahead, assuming that the patella is not subluxated or dislocated.

If the tibial or femoral component is in a mal rotated position, determination of the axial alignment of the lower extremity becomes more complex.[26]

Hence long length radiograph after proper positioning of the patients is a valuable tool in assessing the mechanical axis of the extremity.

Long radiographs are not only essential for accurate assessment of the axial alignment of the lower limb but also necessary for estimating the ‘physiological valgus angle’

The distal femoral cut should be made perpendicular to the mechanical axis of the femur so as to get the correct axial alignment at the end of the surgery. Most of the femoral distal cutting jigs take intra-medullary rod as their reference.

The angle at which the cutting block should be fixed to the intra-medullary alignment rod is determined by the preoperatively measured valgus angle in the full length radiograph.

Thus it is imperative to assess the valgus angle in every patients undergoing knee replacement. In our study, this measurement ranged from 6 to 8 degrees.

In addition, post-operative full length alignment x-ray taken after every case helps in the self assessment of the surgeon regarding the restoration of mechanical axis and thus helps to reduce the learning curve of the individual surgeon and improves the surgical precision.

Using Kettelkamp and Chao's[50] work as reference, when the mechanical axis passed through zone 0 or zone 1 the medial compartment is loaded with 100% of the weight bearing forces. Only when the femero tibial angle was 0 degrees or a valgus angle did the lateral compartment begin to bear weight.[23]

Loading in zone 0 and zone 1 should be avoided because Zone 0 and zone 1 alignment excessively load the medial compartment and increases the possibility of eventual failure

Zone 2 and zone C results load the knee more normally and their results were uniformly superior to other zone results. With alignment in zone 2 or zone C the kinematics of the joint more closely approaches that of normal knee.

Zone 3 results are slightly inferior in that they load the lateral compartment and result in more cases of lateral compartment wear than zone 2 or zone C.

Zone 4 should be avoided because it indicates that excessive medial release has occurred at the time of ligament balancing and will result in instability. None of our cases are zone 3 or zone 4 aligned.

Thus under correction (zones1 or zone 0) will result in excessive loading of the medial compartment and increased tendency for loosening of the components. Over correction (zone 3, 4 and 5) will result in an increased incidence of lateral wear and instability.

William R Kennedy et al in their 51 month follow-up of one hundred consecutive cases conclude that the alignment and position of the component affects the outcome of the procedure by controlling the medial lateral weight distribution.[15] Although the initial postoperative results with a poorly aligned knee may be satisfactory, the long-term results will be affected by the overall alignment.

Jonssson and Lindstrand also make similar conclusion in their series.[51]

It has been observed by various authors that zone 2 and zone C postoperative alignment seems to improve patellar alignment also.[15]

As the knee is aligned in increasing varus, the patella tracks with an increasing load on the medial patellar facet. By observing during surgery the frequency of medial patello femoral cartilage changes in varus knee, it appears that subsequent redirection of patellar forces to lateral patellofemoral cartilage in patient with zone 2 or zone C resultant, mechanical axis would be favorable.

In our series of 15 cases, the preoperative analysis of full length radiograph showed that in about 8 cases the mechanical axis passed through zone 0 and in 3 cases it passed through zone 2. In none of our cases it passed through zone C.

Postoperatively in 7 cases the mechanical axis passed through zone C and in 6 cases it passed through zone 2. Thus in 86.7% of the cases the mechanical axis of the lower limb passed through the favorable alignment of zone 2 and zone C. This is on par with the data available from the literature.[48]

In two of our knees the axis passed through the unfavorable zone I. This includes one varus knee wherein the mechanical axis has deteriorated from zone 2 to zone 1.

In the second case, which is a valgus knee, though the axis had shifted from the most unfavorable zone 0, it is still passes through zone 1, which is less unfavorable.

While intra-operative problems due to the increased BMI of the patient may be the cause for failure in the first case, the learning curve of the surgeon to valgus knee may be the reason in the second case.

Functional results in these group where the mechanical axis passed through the unfavorable zones were analysed using paired‘t’ test

Score	Preoperative		Postoperative		‘p’ value
	Mean	SD	Mean	SD	
Knee Score	51	4.2426	65.5	26.16295	p=0.62226
Functional score	55	4.2426	62.5	17.67767	p=0.71310

While the comparative analysis in all the patients in the study group showed a stastically significant improvement between the preoperative and postoperative knee scores, the unfavorable group did not show any significant improvement in the knee scores.

Thus a strong correlation exists between the functional outcome and the axial alignment of the extremity postoperatively.

Computer assisted navigation system provides a significant improvement of prosthesis and limb alignment in TKA. They offer additional information intra-operatively and might therefore simplify the procedure.

They not only help in taking accurate bony cuts and proper positioning of the implant but also help in soft tissue and ligament balancing. It has been claimed to be accurate to within 1 degrees in the coronal plane resections. The long term analysis on the cost effectiveness of this system is awaited. Dong H et al in their early assessment of the likely cost-effectiveness of this new technology conclude that ‘compared with conventional TKR, computer-assisted TKR is a cost-saving technology in the long-term and may offer small additional QALYs (quality-adjusted life years) [42,43,44,45]

Though the BMI is within the normal range, in our population, osteoarthritis of knee had developed comparatively at an earlier age. This may due to the practices adopted by people in this part of the world like squatting, kneeling and cross legged sitting which results in abnormal loading of the joint.

The level of awareness among the public about the disease process, its natural course and the available treatment modalities including replacement surgery should be brought up.

Valgus angle must be assessed in individual patients by taking full length radiographs pre-operatively to get axial alignment corrected.

Post-operative study of mechanical axis in full length weight bearing x-ray is a must to assess the restoration of mechanical axis back to normal.

Knee scores and functional scores have improved significantly in those groups of patients where there was restoration of mechanical axis. In the rest where the mechanical axis had not been restored the scores have not improved significantly.

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STUDY OF CORONAL ALIGNMENT OF KNEE AFTER TOTAL KNEE REPLACEMENT

PROFORMA

Patient Name **Surgeon's Name**

Age **Sex** **IP No** **Pre-Op/Post-OP**

Address

DOA
DOD
DOS

Phone No **Height**

Occupation **Weight**

KNEE SCORE

Pain **50 (Maximum)**

Walking ☐

None	35
Mild or occasional	30
Moderate	15
Severe	0

Stairs ☐

None	15
Mild or occasional	10
Moderate	5
Severe	0

R.O.M. **25 (Maximum)**

5°= 1 point ☐

Stability **25 (Maximum)**

Medial/Lateral ☐

0-5 mm	15
5-10 mm	10
> 10 mm	5

Anterior/Posterior

0-5 mm	10
5-10 mm	8
> 10 mm	5

Deductions

Extension lag

None	0
<4 degrees	-2
5-10 degrees	-5
>11 degrees	-10

Flexion Contracture

< 5 degrees	0
6-10 degrees	-3
11-20 degrees	-5
> 20 degrees	-10

Malalignment

5-10 degrees	0
(5º = -2 points)	

Pain at rest

Mild	-5
Moderate	-10
Severe	-15
Symptomatic plus objective	0

Knee Score 100 (Maximum) =

FUNCTIONAL SCORE

Walking

Unlimited	55
10-20 blocks	50
5-10 blocks	35
1-5 blocks	25
< block	15
Cannot	0

Stairs Up

Normal	15
Hands balance	12
Hands pull	5
Cannot or bizarre	0

Stairs Down

Normal	15
Hands balance	12
Hands hold	5
Cannot or bizarre	0

Chair

Normal	15
Hands balance	12
Hands pull	5
Cannot	0

Functional Deductions

Cane	-2
Crutches	-10
Walker	-10

Functional Score 100 (Maximum) =

Radiological Evaluation

Date of X-ray

Physiological valgus angle

Preoperative Tibial zone

Postoperative Tibial zone

CASE 7
PREOPERATIVE

CASE 7
PREOPERATIVE

CASE 7
POST OPERATIVE

CASE 7
POST OPERATIVE

CASE 7
PREOPERATIVE

ZONE 0

CASE 7
POSTOPERATIVE

ZONE 2

CASE 8, 9
PREOPERATIVE

CASE 8, 9
POST OPERATIVE

CASE 8, 9
PREOPERATIVE

ZONE 0 **ZONE 0**

CASE 8, 9
POST OPERATIVE

RT – ZONE C **LT - ZONE 2**

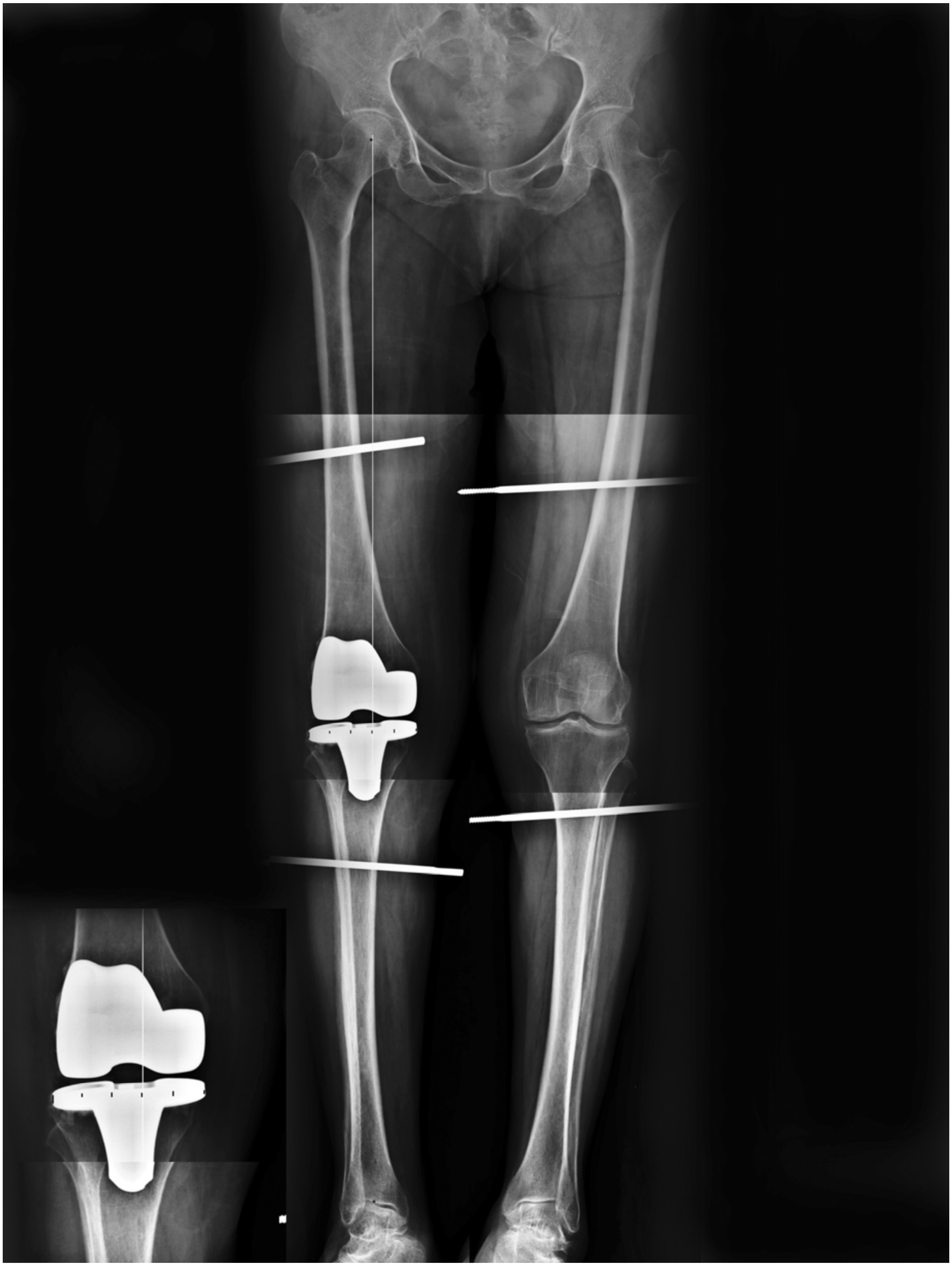
CASE 12
PREOPERATIVE

CASE 12
POST OPERATIVE

CASE 12
PREOPERATIVE

ZONE 3

CASE 12
POST OPERATIVE



ZONE C

CASE 12
POST OPERATIVE
KNEE EXTENSION

POST OPERATIVE
KNEE FLEXION

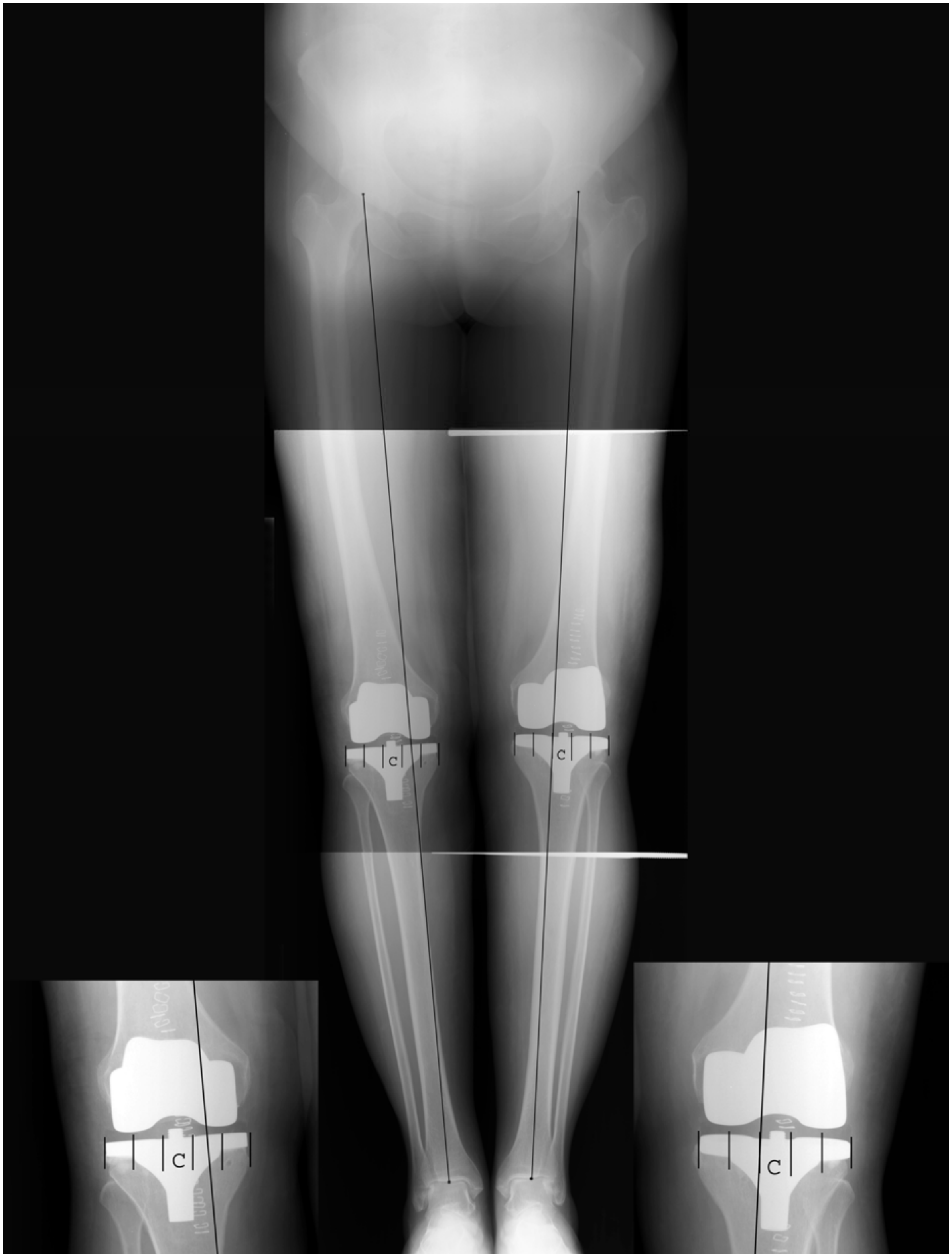
CASE 13, 14
PRE OPERATIVE

CASE 13, 14
POST OPERATIVE

CASE 13,14
PREOPERATIVE

ZONE 1 **ZONE 2**

CASE 13,14
POST OPERATIVE



ZONE 2 **ZONE C**

CASE 13, 14
PREOPERATIVE *L*

CASE 13,14
PREOPERATIVE *R*

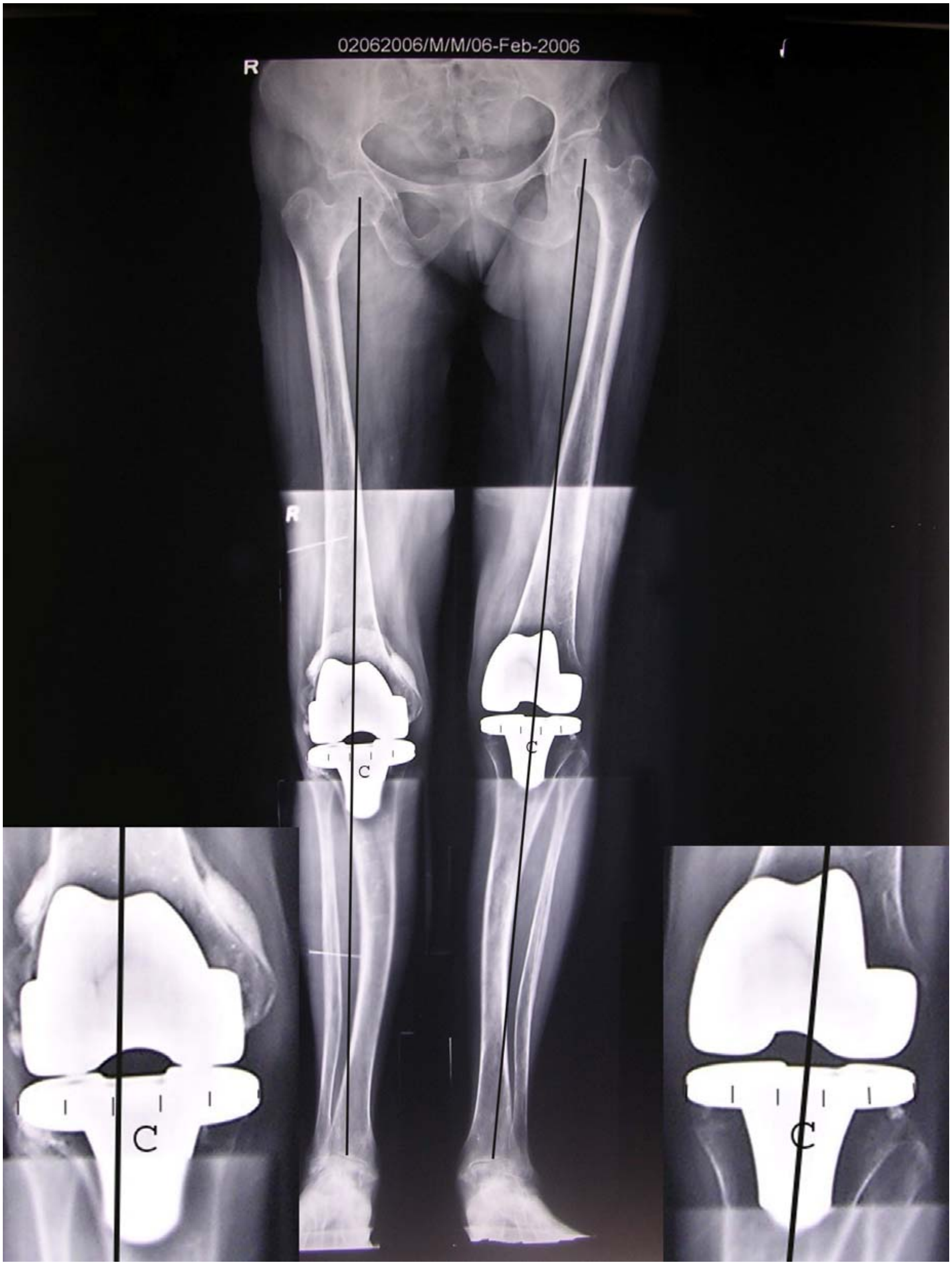
CASE 13,14
II POSTOP WEEK *L*

CASE 13,14
II POST OP WEEK *R*

CASE 1, 2
PREOPERATIVE

ZONE 4 **ZONE 2**

CASE 1, 2
POSTOPERATIVE



ZONE C **ZONE C**

CASE 3
PREOPERATIVE

ZONE 2

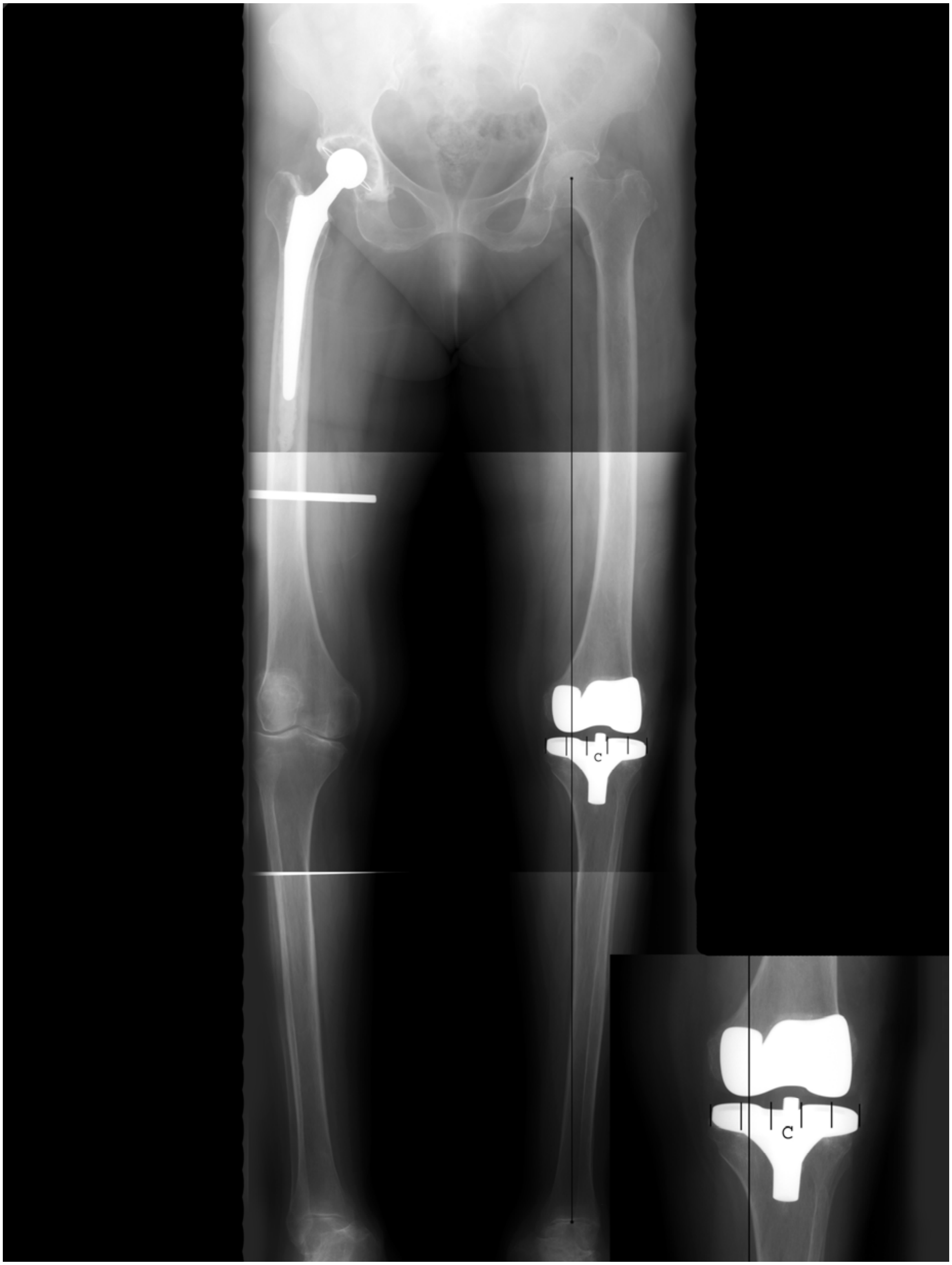
CASE 3
POSTOPERATIVE

ZONE 1

CASE 10, 11
POST OPERATIVE

ZONE C **ZONEC**

CASE 15
POST OPERATIVE



ZONE 2

MASTER CHART

No	Age	Sex	Ht	Wt	BMI	Indication	Side	Deformity	KL score	Valgus Angle degree	Preop Zone	Postop Zone	Preop KS	Postop KS	Preop FS	Postop FS
1	47	F	154	48	20.25	RA	R	Valgus	4	6	4	C	38	85	47	72
2	47	F	154	48	20.25	RA	L	Varus	3	7	2	C	42	89	50	72
3	62	F	157	80	32.52	OA	L	Varus	4	7	2	1	54	47	58	50
4	42	F	158	55	22.08	RA	R	Valgus	3	7	0	1	48	84	52	75
5	42	F	158	55	22.08	RA	L	Valgus	3	7	0	2	50	86	52	75
6	65	F	153	61	26.06	OA	R	Varus	4	7	0	2	45	83	48	80
7	62	M	162	65	24.80	OA	R	Varus	4	8	0	2	41	95	50	86
8	66	F	150	64	28.44	OA	R	Varus	4	7	0	C	55	92	54	78
9	66	F	150	64	28.44	OA	L	Varus	4	7	0	2	53	90	54	78
10	58	M	165	63	23.16	OA	R	Varus	4	7	0	C	41	92	48	86
11	58	M	165	63	23.16	OA	L	Varus	4	7	0	C	40	92	48	86
12	76	F	150	55	24.44	RA	R	Valgus	2	7	3	C	53	78	57	71
13	62	F	154	54	22.78	OA	R	Varus	2	7	1	2	50	88	52	86
14	62	F	154	54	22.78	OA	L	Varus	3	7	2	C	45	92	48	86
15	63	F	154	52	21.94	OA	L	Valgus	4	7	4	2	42	84	44	76