IDENTIFICATION OF EARLY PREDICTORS OF HIP AND KNEE ARTHROPLASTY FAILURE BY DEVELOPING A COMPUTER BASED IMAGE-ANALYSIS METHOD ON RADIOGRAPHIC IMAGES

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Astratto

Artroplastica e di ginocchio sono i due principali interventi chirurgici di successo nel campo medico, ma sono necessari i fallimenti in queste protesi da considerare. Anca e ginocchio può essere definita come la chirurgia, che prevede la sostituzione dell'anca e del ginocchio danneggiato da impianti idonei, che consiste femorale e componente acetabolare. I risultati di questi interventi dipendono da diversi fattori quali fattori paziente, fattori chirurgo e fattori implantari. Anche se, la maggior parte delle protesi dell'anca e del ginocchio sono di successo, ci sono alcuni pazienti, i cui risultati in fallimento chirurgia. Fuori di questi tre fattori, il fallimento per il fallimento paziente è a causa delle loro funzioni di età e preoperatorie, in cui non v'è alcun ruolo per ingegneri biomedici. Il fattore di impianto non è discusso qui.

Il fattore chirurgo, che è uno dei fattori importanti, sono considerati. Durante l'intervento chirurgico, il corretto fissaggio degli impianti è necessaria. Con il progresso della tecnologia e Imaging, la fissazione della protesi può essere analizzato immagine radiografia utilizzando. L'immagine radiografica, che viene preso dopo l'intervento chirurgico, chiamato l'immagine post-radiografica può essere valutata e la probabilità di guasti può essere trovato. I fallimenti come allentamento, sono tutti ultime fasi del guasto, che possono essere trovati utilizzando opportune radiografie follow-up. I primi fallimenti, come dislocazioni, il rapimento limitata possono essere trovati tramite radiografia postoperatoria, che viene assunto subito dopo l'intervento chirurgico. Dal singolo radiografia presa, la possibilità di insorgenza di dislocazione può essere trovato.

In questo lavoro, la valutazione delle radiografie postoperatorie è fatto semi-automaticamente e il normale e anormale o il fallimento dell'anca e del ginocchio sono trovati. Il calcolo semiautomatico è dovuto ad alcune limitazioni che è stato affrontato durante la fase di sviluppo di questo lavoro, che è stato spiegato nel rapporto in dettaglio. In questo lavoro, i primi predittori di anca e ginocchio fallimento arthroplastica con metodo di analisi delle immagini sulle immagini radiografiche sono state trovate ed i risultati e il metodo di valutazione sono state spiegate.
Abstract

Hip arthroplasty and knee arthroplasty are the two major successful surgeries in the medical field, but the failures in these arthroplasties are needed to be considered. Hip arthroplasty and Knee arthroplasty can be defined as, the surgery, that involves the replacement of injured hip and knee by suitable implants, that consists of femoral and acetabular component. The results of these surgeries depend on different factors such as patient factors, surgeon factors and implant factors. Though, most of the Hip and Knee arthroplasties are successful, there are some patients, whose surgery results in failure. Out of these three factors, the failure for patient failure is due to their age and preoperative functions, in which there is no role for biomedical Engineers. The implant factor is not discussed here.

The surgeon factor, which is one of the important factors, are considered. During surgery, the proper fixation of the implants is necessary. With the advancement in Technology and Imaging, the fixation of the implant can be analysed using radiograph image. The radiographic image, which is taken after the surgery, called the post-radiographic image can be evaluated and the probability of failures can be found. The failures such as loosening, are all latter stages of failure, which can be found using proper follow-up radiographs. The early failures such as dislocations, limited abduction can be found using postoperative radiograph, that is taken immediately after the surgery. From the single radiograph taken, the possibility of occurrence of dislocation can be found.

In this work, the evaluation of postoperative radiographs is done semi-automatically and the normal and abnormal or failure hip and knee are found. The semi-automatic calculation is due to some limitations that was faced during the development stage of this work, which was explained in the report in detail. In this paper, the early predictors of hip and knee arthroplasty failure using imaging analysis method on radiographic images were found and the results and method of evaluation were explained.
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1.1 Anatomical terms

LIST OF ABBREVIATIONS

1. THA- Total Hip Arthroplasty
2. TKA- Total Knee Arthroplasty
3. DICOM- Digital Imaging and COmmunication in Medicine
4. MATLAB- MATrix LABoratory
5. PCO- Posterior Condylar Offset
AIM AND OBJECTIVES

Hip arthroplasty and knee arthroplasty are the two major important surgeries all over the world. Almost, 1.4 million hip arthroplasties and 1.1 million knee arthroplasties are done annually. The regular follow-ups are done after surgery to evaluate the possibility of risk of failure. The follow-up procedure should be regular and periodic. Because of this regular follow-ups, time and money gets spent. To overcome this follow-up procedures and to find out the risks of failure of Hip arthroplasty earlier, the semi-Automatic method of evaluation of parameters to find the failure of hip arthroplasty. The MATLAB software is used for the evaluation of the parameters to analyse the result of two surgeries. Radiographic images are used for evaluation of arthroplasties. Radiographic images, which are taken after surgery are used for the evaluation. Post-radiographs are the radiographic images, that are obtained after surgery, which may be taken immediately or may be later can be used for evaluation. The radiographic images are provided by Humanitas hospital, Milano, which are in the standard DICOM format. The obtained results can be compared with the result, given by the Hospital.

For the evaluation of Hip arthroplasty failure, two parameters are measured, one is Horizontal centre of rotation and another one is Acetabular inclination. The abnormal functionality such as Dislocation and limited abduction can be found by evaluating these two parameters at the earlier stage of surgery. The two parameters need not give same result for a single image, as two different parameters are evaluated in the same radiograph. Hence, the radiographic image can be considered as normal or pathologic only after evaluating both parameters. The calculation of acetabular inclination is simpler, as the output must be in the range between two different values, hence the marking of location on the radiographic image need not be very accurate, while the procedure to measure horizontal centre of rotation is tedious that the output should be very accurate, so that the marking of locations on the radiographic image for calculating this parameter should be precise. The output for the acetabular inclination is the standard value, hence double-sided arthroplasty can be evaluated, whereas the horizontal centre of rotation cannot be evaluated for double sided arthroplasty, as this evaluation is done by comparing the output value from the normal hip and the implant hip from the same image.
Knee arthroplasty the one of the major successful surgeries in the world. The failure rate of this surgery is low, but the low percentage of failure is necessary to evaluate earlier. Like hip arthroplasty, knee arthroplasty also needs follow-ups. To prevent this, the evaluation of radiographic image, taken immediately after surgery will be done. From the postoperative radiograph, the parameters can be evaluated. In knee arthroplasty, two parameters, mechanical analysis and posterior condylar offset (PCO) ratio are analysed. Unlike hip arthroplasty, these parameters will not provide information about any specific disfunction, instead the normality or abnormality of the implant, that is fixed after surgery can be found. The two parameters, mechanical analysis and PCO ratio, whose measurements are complicated that the value of output should be very accurate. The output value for the two parameters are standard. The evaluation can be done for even double-sided arthroplasty, normal knee bone is not need needed for verification like Hip.
CHAPTER-1

INTRODUCTION

1.1 Introduction of Hip

The hip joint is a ball-and-socket type joint and is formed where the thigh bone (femur) meets the pelvis. The femur has a ball-formed head on it that fits right into a socket fashioned within the pelvis, known as the acetabulum. Large ligaments, tendons, and muscle groups around the hip joint hold the bones (ball and socket) in place and maintain it from dislocating. The anatomical image of the normal hip is demonstrated by the figure1.1 shown. [16]

Regularly, a smooth pad of sparkly white hyaline (or articular) ligament around 1/4-inch-thick covers the femoral head and the hip bone socket. The articular ligament is kept smooth by liquid made in the synovial layer (joint covering). Synovial liquid and articular ligament are an elusive blend—multiple times more elusive than skating on ice and four to multiple times more noteworthy elusive than a metal or plastic hip substitute. Synovial liquid is the thing that
enables us to flex our joints under incredible weight without wear. Since the ligament is smooth and elusive, the bones move against one another effectively and without pain.[4]

At the point when the ligament is harmed, regardless of whether auxiliary to osteoarthritis (mileage type joint inflammation) or injury, joint movement can wind up difficult and restricted. The hip joint is surely one of the biggest joints inside the body and is a prime weight-bearing joint. Weight bearing weights on the hip at some phase in walking can be five occurrences somebody's edge weight. A sound hip can help your weight and can enable you to go without throb. Changes in the hip from turmoil or harm will influence your stride and area irregular strain on joints above and beneath the hip. It pays attention to momentous strain to harm the hip due to the solid, immense bulk of the thighs that guide and stream the hip

1.1.1 Anatomy of Hip

Anatomical phrases permit us to explain the frame and body motions more exactly.

Table-1.1 Anatomical terms

<table>
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<th>S.no</th>
<th>Anatomical terms</th>
<th>Meaning</th>
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<tr>
<td>1</td>
<td>Anterior</td>
<td>the abdominal side (front) of the hip</td>
</tr>
<tr>
<td>2</td>
<td>Posterior</td>
<td>The back side of the hip</td>
</tr>
<tr>
<td>3</td>
<td>Medial</td>
<td>the side of the hip closest to the spine</td>
</tr>
<tr>
<td>4</td>
<td>Lateral</td>
<td>The side of the hip farthest from the spine</td>
</tr>
<tr>
<td>5</td>
<td>Abduction(1)</td>
<td>Move away from the body</td>
</tr>
<tr>
<td></td>
<td>Abduction(2)</td>
<td>Move towards the body</td>
</tr>
<tr>
<td>6</td>
<td>Proximal</td>
<td>Located near to the point of attachment or reference</td>
</tr>
<tr>
<td>7</td>
<td>Distal</td>
<td>located farthest from the point of attachment or reference</td>
</tr>
<tr>
<td>8</td>
<td>Inferior</td>
<td>located beneath, under or below; under surface</td>
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</table>

The hip is a ball-and-attachment joint like the shoulder however is significantly steadier. The equalization inside the hip starts with a profound attachment—the hip bone socket. Extra solidness is given by the encompassing muscles, hip container and related tendons. On the off chance that you think about the hip joint in layers, the most profound layer is bone, at that
Point tendons of the joint case, at that point muscles are on top. Different nerves and veins supply the muscles and bones of the hip. The anatomy of the hip is shown by the figure 1.2. [1,3]

1.2 Anatomy of the Hip

1.1.2 Problems associated with Hip

The following are the list of the main clinical problems associated to the hip which may lead to the procedure of arthroplasty

1. Osteoarthritis
2. Rheumatoid arthritis
3. Ankylosing spondylitis
4. Bone fracture
5. Developmental dysplasia of the hip
6. Perthes’ disease
7. Irritable hip syndrome
8. Slipped capital femoral epiphysis
9. Post traumatic arthritis
10. Infection

1.1.3 Hip Arthroplasty

x-ray is used to diagnose these problems and if the problems are found positive from the obtained radiographic images, Hip Arthroplasty is done. The arthroplasty procedure is explained below.

Step-1 The damaged bone and cartilage are removed and replaced with prosthetic Components.

Step-2 The damaged femoral head is removed and changed with a metallic stem that is positioned into the hole centre of the femur. The femoral stem may be either cemented or "press in shape" into the bone.

Step-3 A metallic or ceramic ball is positioned at the top part of the stem. This ball replaces the broken femoral head that turned into eliminated.

Step-4 The broken cartilage surface of the socket (acetabulum) is eliminated and changed with a metallic socket. Screws or cement are occasionally used to hold the socket in area.

Step-5 A plastic, ceramic, or metal spacer is inserted between the new ball and the socket to allow for a smooth gliding surface.

The Hip arthroplasty was first performed in 1960, hip replacement surgery is one of the most successful operations in all of medicine. Since 1960, enhancements in joint alternative surgical strategies and era have substantially multiplied the effectiveness of general hip replacement. According to the Agency for Healthcare Research and Quality, more than 300,000 total hip replacements are performed each year in US.\textsuperscript{151}

Radiographs are taken after the surgery in-order to review and evaluate the results of the surgery., this is called as postoperative radiographs. The postoperative radiographs are used to evaluate the possibilities of occurrence of failure in future. This includes, Dislocation, Aseptic loosening, Limited abduction etc.
1.1.4 Components of Hip Implant

There are two basic components of hip bone, acetabular and femoral component. The total hip bone is comprised into two different components, which are connected to one another in order to recreate the functions of the hip bone. The improper placement of these component or the selection of imperfect implant leads to failure of the prosthesis.

Acetabular component

The acetabular cup is the component that’s located into the acetabulum (hip socket). Cartilage and bone are removed from the acetabulum and the acetabular cup is attached using friction or cement. Some acetabular cups are one piece, at the same time as others are modular. One-piece (monobloc) shells are both UHMWPE or metal, they have got their articular floor machined on the inner floor of the cup and do no longer rely on a locking mechanism to hold a liner in region. A monobloc polyethylene cup is cemented in location whilst a steel cup is held in place through a metal coating on the outside of the cup. Modular cups include two portions, a shell and liner. The shell is made of metal; the out of doors has a porous coating even as the inside carries a locking mechanism designed to simply accept a liner. Two styles of porous coating used to form a friction healthy are sintered beads and a foam metal layout to imitate the trabeculae of cancellous bone and preliminary balance is inspired with the aid of under-reaming and insertion pressure. Permanent fixation is done as bone grows onto or into the porous coating. Screws can be used to lag the shell to the bone providing even greater fixation. Polyethylene liners are located into the shell and connected with the aid of a rim locking mechanism; ceramic and steel liners are attached with a Morse tape. The acetabular component, manufactured by the Stryker is displayed in the figure 1.3.[17]

Fig-1.3 Acetabular component of the Prosthesis
**Femoral component**

The femoral component is the component that fits in the femur (thigh bone). Bone is eliminated and the femur is formed to simply accept the femoral stem with attached prosthetic femoral head (ball). There are two types of fixation: cemented and uncemented. Cemented stems use acrylic bone cement to form a mantle between the stem and to the bone. Uncemented stems use friction, form and surface coatings to stimulate bone to rework and bond to the implant. Stems are made of a couple of materials (titanium, cobalt chromium, stainless-steel, and polymer composites) and that they can be monolithic or modular. Modular components consist of various head dimensions and/or modular neck orientations; those attach via a taper much like a Morse taper. These options permit for variability in leg duration, offset and model. Femoral heads are made from steel or ceramic material. Metal heads, manufactured from cobalt chromium for hardness, are machined to size and then polished to reduce wear of the socket liner. Ceramic heads are greater easy than polished steel heads, have a lower coefficient of friction than a cobalt chrome head, and in principle will wear down the socket liner more slowly. As of early 2011, observe-up research in patients have not demonstrated huge discounts in wear rates among the diverse styles of femoral heads in the marketplace. Ceramic implants are more brittle and may spoil after being implanted. The femoral component from the Stryker manufacturer is shown in the figure 1.4.\[26\]

![Fig-1.4 Femoral component of the Implant](image)
1.2 Introduction of Knee

The knee is one among the largest and maximum complicated joints in the frame. The knee joins the thigh bone (femur) to the shin bone (tibia). The smaller bone that runs along the tibia (fibula) and the kneecap (patella) are the alternative bones that make the knee joint. The knee joint is displayed in the figure 1.5.\textsuperscript{[20]}

![Fig-1.5 Knee Joint](image)

Tendons connect the knee bones to the leg muscle mass that move the knee joint. Ligaments join the knee bones and provide balance to the knee

- The anterior cruciate ligament prevents the femur from sliding backward on the tibia (or the tibia sliding forward on the femur).
- The posterior cruciate ligament prevents the femur from sliding forward on the tibia (or the tibia from sliding backward at the femur).
• The medial and lateral collateral ligaments save you the femur from sliding facet to side. Two C-fashioned pieces of cartilage referred to as the medial and lateral menisci act as shock absorbers between the femur and tibia. Numerous bursae, or fluid-stuffed sacs, assist the knee pass smoothly.19

### 1.2.1 Anatomy of knee

The knee is a hinge joint that is responsible for weight-bearing and motion. It consists of bones, meniscus, ligaments, and tendons. The anatomy of the knee is displayed in the figure 1.6.18

![Fig-1.6 Anatomy of the Knee](image)

The knee is designed to fulfil several functions:

- Allow the flexion and extension of the decrease leg relative to the thigh
- support the body in an upright position without the need for muscles to work
- helps to lower and raise the body
- provides stability
• acts as a shock absorber
• allows twisting of the leg
• makes walking more efficient
• helps propel the body forward
• acts as a hinge that allows our lower leg and foot to swing easily forward or back as we walk, run, or kick.

1.2.2 Problems associated with Knee

The following are the list of the main clinical problems associated to the hip which may lead to the procedure of arthroplasty
1. Knee osteoarthritis
2. Anterior cruciate ligament tear
3. Posterior cruciate ligament tear
4. Rheumatoid arthritis
5. Gout
6. Septic arthritis
7. Meniscal tear.

1.2.3 Knee Arthroplasty

Radiographic images are used to diagnose knee arthroplasty. Once surgery is done, the postoperative radiographs are used to revive and evaluate the results of the surgery as like hip arthroplasty.

The maximum commonplace reason for knee substitute surgical procedure is to relieve excessive ache caused by osteoarthritis. People who need knee replacement surgical procedure commonly have problems strolling, mountaineering stairs, and going in and out of chairs. Some additionally have knee ache at relaxation. Knee replacement surgery or knee arthroplasty can help relieve pain and restore function in severely diseased knee joints. The procedure involves cutting away damaged bone and cartilage from your thighbone, shinbone and kneecap and replacing it with an artificial joint (prosthesis) made of metal alloys, high-grade plastics and polymers. In determining whether a knee replacement is right for you, an
orthopaedic surgeon assesses your knee’s range of motion, stability and strength. X-rays help determine the extent of damage.\textsuperscript{201}

Knee replacement surgery, like any surgery, carries risks. They include Infection, Blood clots in the leg vein or lungs, Heart attack, Stroke, Nerve damage

### 1.2.4 Components of Knee Implant

There are two basic components of knee bone, acetabular and femoral component. The total knee bone consists of two different components, which are connected to one another in order to mimic the knee joint. The improper placement of these component or the selection of imperfect implant leads to failure of the prosthesis.

The components of the knee implant are shown in figure 1.7.\textsuperscript{211}

![Fig-1.7 total knee replacement implant.](image-url)
The decrease stops of the femur - The metallic femoral component curves around the quilt of the femur (thighbone). It is grooved so the kneecap can move up and down smoothly against the bone as the knee bends and straightens.

The top floor of the tibia - The tibial component is typically a flat steel platform with a cushion of sturdy, long lasting plastic, referred to as polyethylene. Some designs do no longer have the steel element and fix the polyethylene at once to the bone. For additional stability, the metal portion of the component may have a stem that inserts into the centre of the tibia bone.

The back surface of the patella - The patellar issue is a dome-formed piece of polyethylene that duplicates the shape of the patella (kneecap). In a few cases, the patella does now not need to be resurfaced.

1.3 Design of the Implants

The implants are designed to mimic the actual organ. There are wide variety of implants designed, all over the world. The design and fixation of these implants play a vital role in surgery. The implants comprise from artificial tooth to artificial vital organs.

1.3.1 Hip implants

Metal on Metal (MOM) – This is while the socket and the ball components are all made from steel. The metal components can be a combination of metals like titanium, cobalt-chromium alloys, or cobalt mixed metals. The metal on metal hip replacement implant from the Stryker manufacturer is shown in the figure 1.8.

Fig-1.8 Metal on Metal Hip replacement implant
Polyethylene and Metal on Polyethylene (MOP)—Polyethylene is a high-quality metal-free plastic. The socket or acetabular liner is usually made of this plastic. In addition, other components can be made of metal and covered with plastic. When a socket is plastic and the ball is metal, this is considered MOP. The metal on polyethylene hip replacement implant manufactured by Stryker is shown in figure 1.9.\cite{42}

![Fig-1.9 Metal on polyethylene hip replacement implant](image)

Ceramic on Metal (COM), Ceramic on Polyethylene (COP), Ceramic on Ceramic (COC)—Ceramic hips are less common, and a material not used by all surgeons. Ceramic material is often used in combination with special metal components or plastic components for those allergic to metals. Although ceramic parts are long lasting, historically, they had been extra fragile than metallic additives. However, this is converting. Today’s ceramic parts are argued to outlast metal part. The ceramic on metal implant from the Depuy manufacturer is shown in the figure 1.10\cite{24}

![Fig-1.10 ceramic on metal hip replacement implant](image)
1.3.2 Knee implants

The knee is considered a "hinge" joint due to its capability to bend and straighten like a hinged door. The knee is much more complex because the bone surfaces roll and glide as the knee bends.

Current implant designs recognize the complexity of the joint and greater carefully mimic the motion of a normal knee. For example, ligaments keep the joint stable in a healthy knee. Some implant designs preserve the patient's own ligaments, while others substitute for them.

Gender-specific implants. Many manufacturers have developed components for the end of the thighbone which more closely match the average woman's knee. Currently, there is no research to show that "gender specific" implants last longer or provide better function than standard implants.

Bicruciate-Retaining designs- In most total knee substitute techniques, the anterior cruciate ligament is removed to permit for precise placement of the implant. In bicruciate-keeping designs, each the anterior and posterior cruciate ligaments are stored. The rationale for this kind of design is that by saving both ligaments, the knee will characteristic and experience greater like a non-changed knee. Bicruciate-maintaining additives are particularly new to the market and there aren't yet many researches that display the professionals and cons of this design.

Unicompartmental Implants- Although replacing the entire knee joint is the maximum common manner, patients can benefit from just a partial knee substitute. If only one side of the knee joint is damaged, smaller implants can be used (unicompartmental knee replacement) to resurface just that side.1251

Posterior-stabilized designs- One of the most normally used kind of implant in overall knee replacement is a posterior-stabilized thing. In this design, the cruciate ligaments are eliminated and parts of the implant alternative for the posterior cruciate ligament (PCL). The tibial element has a raised surface with an inner publish that suits right into a special bar (called a cam) inside the femoral element. These components work together to do what the PCL does: prevent the
thighbone from sliding forward too far on the shinbone when you bend your knee. The model of the posterior-stabilized design is shown in the figure 1.8.²²¹

![Fig-1.11 Parts of a posterior-stabilized implant (arrow) replace the PCL.](image)

**Cruciate-Retaining designs** - As the name implies, the posterior cruciate ligament is kept with this implant design (the anterior cruciate ligament is removed). Cruciate-retaining implants do not have the centre post and cam design. This implant can be suitable for a patient whose posterior cruciate ligament is healthful enough to retain stabilizing the knee joint. The sample cruciate-retaining design is shown in figure 1.9.²²¹
1.4 Importance of evaluating Hip and Knee Arthroplasty

The statistical results of hip is 15-year survival, with any revision as an endpoint, for all THRs was 86% (CI: 85.7–86.9) in Denmark, 88% (CI: 87.6–88.3) in Sweden, 87% (CI: 86.4–87.4) in Norway, and 84% (CI: 82.9–84.1) in Finland. Revision risk for all THRs was less in Sweden than in the 3 other countries during the first 5 years. However, revision risk for uncemented THR was less in Denmark than in Sweden during the sixth (HR = 0.53, CI: 0.34–0.82), seventh (HR = 0.60, CI: 0.37–0.97), and ninth (HR = 0.59, CI: 0.36–0.98) year of follow-up.\textsuperscript{[27]}

The survival curve of THA in Italy was found to have Mean value at 7 years is 96.8% (95% CI: 96.4–97.1%).\textsuperscript{[46]}
The statistics of knee arthroplasty is approximately 82% of TKRs last 25 years and 70% of UKRs last 25 years and pooled survival was 96·3% (95% CI 95·7–96·8) at 15 years and 92·0% (90·1–93·8) at 20 years. \[28\]

Based on the results shown above, it is necessary to evaluate the result of the surgery to predict the possible failures of arthroplasty. Hence, the evaluation on postoperative radiographic images are going to be done. In this procedure, a software is going to be used to evaluate the images and the results will be found. The evaluation on images are done manually due to the lack of facilities and data, which will be explained in detail later. A detailed literature review is necessary for the procedure. After reviewing the published journals, the image data for the evaluation, method of evaluation and results will be discussed.

### 1.5 Benefits and Risks of Arthroplasty over other surgery

**Advantages of hip arthroplasty**

1. Relatively lower damage to muscles
2. Lower pain after surgery
3. Faster recovery
4. Lower risk of Dislocation
5. Post-Arthroplasty movement is better

**Disadvantages**

1. Obese people are not recommended
2. Nerve may be affected
3. Wound healing issues. \[39\]

**Advantages of knee arthroplasty**

1. Increase mobility
2. Lesser pain for knee trauma patients
3. More than 90% success rate

**Disadvantages**

1. Heart patients and diabetes patients may have complications in TKA.
2. Post-surgery complications such as infection or blood clots. \[40\]
CHAPTER-2
STATE OF THE ART

Literature review

The literatures, books, journals which are provided for the evaluation of hip and knee arthroplasty failures are explained in this chapter. The journals, which are studied to evaluate both hip and knee arthroplasty include statistical results, imaging techniques, current method of predicting arthroplasty results, automatic method of evaluation, machine learning techniques etc.

2.1 Statistics of Hip and Knee Arthroplasty

Predictors of excellent early outcome after Total Hip Arthroplasty

The authors were explaining the analytical method of predicting the possibility of early failures of Hip arthroplasty in this journal. The authors collected over 1300 hip arthroplasty data and proceeded the Harris Hip Score (HHS) and short form-36 to evaluate the results to predict the early outcomes. The hip function and general health details of the patients were collected before the analysis. The process was carried out for three years to predict the failures. They have used maximal score of HHSs as 100 and validated the results. Multiple logistic regression analysis was used to identify independent predictors of excellent outcome. Using this method, they found that young age and high preoperative HHS were the two important reason for the success rate of hip arthroplasty. Hence, they concluded by saying that young age with less arthritis and lesser trauma patients can withstand the arthroplasty surgery.\[29\]

Total hip replacement: indications for surgery and risk factors for failure

Hip arthroplasty is one of the most successful and cost-efficient surgery. Over 80% of Hip arthroplasty done in United States and United Kingdom accounts for over 65 age of people. Over 90 to 95% of people have success survival rate with hip arthroplasty lasting for 10 years. The authors predicted that the indications for surgery includes pain, functional limitations, stiffness, age etc. after finding one of the reasons mentioned above, arthroplasty is done in this article. After surgery, there are some failure rates occur. The authors predicted that these failures are due to three factors, patient factor, implant factor, surgeon factor. The
implant factor depends on the type of implant used for the patient. The surgeon factor can be accessed by the experience and the success records of surgery done. The patient factor can be calculated by HHS and sort form-36 and after predicting these factors, of these three factors the surgeon factor is very important as the surgeon can decide the possible success or failure of surgery for the patient and the type of implant, that are going to be used for arthroplasty.[38]

**Country-wise results of total hip replacement. An analysis of 438,733 hips based on the Nordic Arthroplasty Register Association database.**

Nordic Arthroplasty Register Association (NARA) reported on around 4,30,000 patients, who have undergone total hp replacements between 1995 and 2011 and the success and failure rate of those data are collected In this journal. The authors have used Kaplan-Meier survival analysis to predict the survival probability with 95% confidence interval. Cox multiple regression, with adjustment for age, sex, and diagnosis, were used to analyze the survival as final output. The authors analyzed the results of success rate in countries such as Sweden, Denmark, Finland and found the success rate is relatively lower in Finland and found that uncemented surgical technique shows reduced success rate among the patients in three countries.[27]

**How long does a knee replacement last? A systemic review and meta-analysis of case series and national registry reports with more than15 years of follow-up**

In this journal, the authors were saying that all the knee replacements will fail, and they insist that predicting the time of failure is important and have done the systemic review over 15 years and found the results. They have considered Unicondylar knee replacements (UKR) and patellofemoral replacements in this journal. Complex surgeries and their results were excluded in the study and survival rate and implant data are studied. The national joint replacement registry data were used in this review. Each series were calculated in the meta-analysis and the pooled survival rate were estimated for 15, 20 and 25 years. They found that over 85% of TKRs were successful for more than 25 years of time and they registered that their pooled data is more accurate than case series data, which are available already.[28]
2.2 Implants used in Hip and Knee Arthroplasty

Recent updates for biomaterials used in total hip arthroplasty

The authors were conducting a literature review and found out the recent advancements and best available biomaterials, that can be used for hip arthroplasty in this paper. They have started searching over 1600 articles and based on high quality and the best answered topics, they have extracted thirty-two articles and studied them. The authors concluded by saying that, besides the high success rate of THA, there are some failures happening, which can be reduced by increasing the longevity of the prosthesis. This can be achieved by the fixation method for the prosthesis, good surgical approach, bearing surfaces. They also concluded by saying that Newer bearing surfaces in-current clinical practice have shown better results. They insist that the scientific community must find the materials which should not only reduce abrasive wear, but also should reduce stress shielding in designs. ongoing research and further improvements in finding the future of biomaterials are anticipated.\[30\]

Lower limb length and offset in total hip arthroplasty

The restoration of biomechanics should be achieved by hip implant. One of the reasons for this failure is leg length inequity or limb length inequity. Data on the influence of operated-limb length and offset on patient satisfaction, hip function, and prosthesis survival after THA are reviewed in this journal. The errors in implant placement results in leg length inequity, which affects in adversely implant function, quality of life and decrease in prosthetic survival rate. The accuracy in placement can be improved by computer-assisted planning or surgery. If the leg lengths are unequal, the revision arthroplasty is considered.\[36\]

An Approach to Developing Customized Total Knee Replacement Implants

The authors, in this journal were approaching to develop a customized implant, which they considered would be a better option for knee arthroplasty. For this purpose, they have obtained the three-dimensional knee model from MRI and CT using image processing techniques. This model is used to develop a patient-specific implant design, biomechanical and creating bone cutting guide blocks. The designers will be developing patient-specific
implants usually, but the knee models are used to predict the muscular forces, joint forces on knee condyles, and wear of tibial polyethylene insert. Hence, every time, a patient is undergoing arthroplasty, the suitable implant can be designed with the help of these techniques, which would improve TKR kinematics and functions, which is also explained in this journal.\[31\]

2.3 Imaging Evaluation

Postoperative radiograph of the hip arthroplasty: what the radiologist should know

The authors were explaining the commercially available arthroplasties and techniques. The authors insist that there are no currently available techniques to evaluate postoperative radiographs. The knowledge on different types of hip arthroplasty and fixing techniques will be useful for postoperative radiographic analysis. The problems such as leg length, acetabular inclination, horizontal centre of rotation, valgus and Varus position complications are all pictorially explained in this journal. From this journal, the knowledge on calculating or predicting the early complications such as dislocation can be inferred. The method to evaluate hip arthroplasty using postoperative radiographs are explained. The possible complications, the types of implants, their designs etc are explained in this article. This journal provides the information about currently available hip arthroplasties and framework of systematic approach to postoperative radiographs and discussed the findings of most common complications.\[1\]

Hip Arthroplasty-Normal and abnormal imaging findings

The authors have attempted the hybrid hip replacement techniques and the evaluation of images are done in this paper. The hybrid hip replacement is the combination of both cement-less and cemented fixation. The cemented acetabular cup has the tendency to lose over time. Hence, the combination of cement-less acetabular cup and the cemented femoral head lasts longer duration. After the hybrid fixation procedure, the imaging evaluation is done. In this evaluation, dislocation, peri-prosthetic fractures and cement extrusion are evaluated. The dislocation accounts for about 3% of failure at the immediate postoperative period. This is due to the poor fixation. Fracture occurs due to the long-term revision prosthesis. The incidence of fractures ranges from 0.1 to 1.0% for cemented components and 3 to 18% for cement-less
components. Besides, these three parameters, there are other parameters include loosening, infection etc are calculated.\textsuperscript{131}

**Determination of the hip rotation centre from landmarks in pelvic Radiograph**

The hip rotation center is defined as the reference point in total hip arthroplasty. The investigation of this reference point among the Turkish papulation enables the identification of HRC using radiographs. The radiographs of 50 men and 50 women with mean age of 46.2 were examined for the review. The measurement of the reference line is done by calculating the distance between HR and tear drop and the HRC and the line tangent tuber ischiadicums. Their ratio was calculated and defined as horizontal HRC and vertical HRC respectively. The ratios were 71 and 34 respectively. considering these values as normal, the THA can be accessed by evaluating HRC by using this value as the reference for Turkish populations.\textsuperscript{371}

**How to Interpret Postoperative X-rays after Total Knee Arthroplasty**

This journal explains the normal post-TKA radiographs and their correct sequence of interpretations. In this journal, the authors have explained how to predict the failure surgery using postoperative radiographs. The method to access the results of TKA by evaluating postoperative radiographs are explained. The comprehensive and detailed study was done in this article to evaluate the radiographs and found that the best way to maintain the success of the surgery is to do regular follow-up or a surgical intervention. Some complications such as loosening can occur after some years of TKA and those can be repaired by follow-up surgery, but the improper fixation and mismatch of implant may cause dislocations, which should be predicted earlier to avoid the complications of surgery.\textsuperscript{41}

**The Posterior Condylar Offset (PCO) Ratio**

In this paper, the posterior condylar offset ratio is explained by the pictorial representation to find PCO. This parameter should be calculated to predict the result of TKA. Like other parameters, this parameter can also be found using radiographic evaluation. the authors were explaining the calculations to find PCO both pre and postoperatively. This
journal is useful in evaluating the results and it is a good aid tool that facilitates further research in this area.\[6\]

2.4 Automatic evaluation and Machine learning

**Computer-aided Diagnosis Systems Based on Medical Image Registration**

In this journal, two things are explained, one is a pre-operative ACL surgery based on MRI was explained. Usually, the ACL reconstruction is related to the placement of femoral bone, hence the procedure is done after reconstruction of ACL. This method proposes the placement of femoral bone during the ACL reconstruction. This method is an automatic method of detecting edges used for surgery, from this method, the automatic detection technique can be inferred. Secondly, postoperative analysis of digital radiograph of TKA was analyzed and the 3-D kinematics were estimated by this method.\[32\]

**Direct plain radiographic methods versus EBRA-Digital for measuring implant migration after Total Hip Arthroplasty**

In this journal, two methods Plain radiograph and digital radiographs were compared for the better output. The precision and the sensitivity were the two parameters, which needs to more accurate foe the better results. The precision was measured with 95% confidence interval and the output obtained from the plain radiographs are better and has more precision compared to digital radiographs. Hence, they conclude by saying that proper method of standardizing plain radiographs improves precision, but this lasts for short term use, for longer term, this method is inferior to digital radiographs, which employs quality control a measurement algorithm to measure migration from digitized radiographs.\[33\]
CHAPTER-3

DATA DESCRIPTION

3.1 Types of data used

Radiographic images are used for evaluating the parameters. Normally, x-rays are being taken before and after arthroplasty, which is being used to access the result.

3.2 Radiographic image of Hip and Knee

3.2.1 Hip Arthroplasty

The hip joint can be imaged under different points. A standard hip X-beam examination by and large incorporates an anteroposterior (PA) picture and a horizontal picture. In a perfect world, the AP picture indicates both hip joints (which carefully makes it a pelvis X-beam) to permit examination with the other hip. The parallel bearing might be picked in axiolateral pictures or a frog leg sidelong picture. The different headings are clarified in more detail underneath.

• Anteroposterior view

The patient is set on his/her back and the X-beams will go through the hip joint from foremost to back as shown in figure 3.1.}\[9]}

![Fig-3.1 Technique for obtaining AP image of the hip.](image-url)
The leg is inside turned 15° - 20° to accomplish femoral anteversion. This will expand the femoral neck, improving its evaluability. At the point when the leg is turned remotely, the more noteworthy trochanter will extend over the neck and improve imaging of the lesser trochanter [7] as displayed in figure 3.2.

![Fig-3.2 Hip image with internal rotation and external rotation](image)

### 3.2.2 Knee Arthroplasty

Most cost-effective and commonest method of follow-up. Baseline radiographs should be obtained immediately post-operation.

- **Anteroposterior view**
  
  1. Mechanical axis corrected to 0 degrees, results in femoral component placed 5-9 degrees valgus to long axis of femur.
  
  2. Tibial component: aligned perpendicular to long axis of tibia
  
  3. Polyethylene (radiolucent) spacer in tibiofemoral joint space: equal width medially and laterally. NB: Beam angle, patient positioning or post-op flexion contracture may distort this.

The anterior-posterior view and the lateral view of the knee joint are shown in the figure 3.3 and figure3.4.
• Lateral view
  1. femoral component: perpendicular to long femoral axis, unless surgeon has chosen to flex component by up to 3 degrees
  2. tibial component: perpendicular to long tibial axis or posteriorly inclined by up to 5 degrees
  3. patella: anterior and articular sides parallel to each other. Oblique patella on true lateral view suspicious for subluxation, patella alta for patellar tendon rupture, and significant patella baja for quadriceps tendon rupture.\[8\]

3.3 Pre and Post-operative Radiographs

The preoperative radiographs are taken to check the status of the injured or affected hip or knee. The radiographs are evaluated by analysing the femoral and acetabular component in hip and knee. If both these components are abnormal, the surgeon will decide to proceed with arthroplasty or any other medical procedure, based on the magnitude of abnormality. The pre and postoperative Hip radiograph image is shown in figure 3.5.\[44\]

If the surgery is necessary, the surgeon will advise the patient to undergo surgery and after surgery, radiographs will be taken in order to access the quality of the surgery. This is
called post radiograph evaluation. Based on the results of the post radiographic evaluation result, the physician may access the quality of the surgery and can conclude the restoration of the hip performance and the life of the implant in duration of time. Hence, the radiographic evaluation is very important factor in pre and post-surgery.

![Fig-3.5 Pre and Postoperative radiograph of hip](image)

The post-surgery radiographs can be accessed by evaluating some parameters and analysing the result of the surgery will be discussed in this journal. The images, that are used for evaluation are obtained from the Humanitas hospital.

Humanitas is a highly specialized hospital, a research center and a university teaching center. Inside the polyclinic, accredited with the National Health Service, specialized centers for the treatment of cancer, cardiovascular, neurological and orthopedic diseases are merged, as well as an Eye Center and a Fertility Center. Humanitas is also equipped with a highly specialized EAS First Aid. Hence, the obtained outputs were verified with the actual results of the image, obtained from the hospital. There are total of 20 image data, obtained from the hospital. The pre and postoperative Knee radiograph is shown in figure 3.6.
3.4 Image format

The x-ray image, which are used for the evaluation are usually in DICOM format, which cannot be evaluated directly in the MATLAB software. Hence, it will be converted from the DICOM format to JPEG format by rewriting the image format in-order to evaluate the radiographic image. The importance of this conversion of format will be demonstrated by the figure 3.7.
CHAPTER-4

PROPOSED METHODOLOGY

4.1 Method description

In this work, the status and results of the post-surgery of hip and knee were evaluated. To evaluate this, radiographic image is being used. This work comprises two main categories, Hip and Knee. The parameters, which can help accessing the results of Hip and Knee Arthroplasty was evaluated.

4.2 Software used

To analyse the radiographic image, there are wide variety of software and tools available. From those, Matlab2007a version of software was used. The main advantages of MATLAB over other software in image processing are listed below,

- A very large (and growing) database of integrated algorithms for photo processing and computer imaginative and prescient applications.[34]
- The MATLAB Desktop environment, which allows us to work interactively with your data, helps us to keep track of files and variables, and simplifies common programming/debugging tasks
- The potential to examine in a wide type of both not unusual and domain-unique image formats.
- The capability to name outside libraries, including Open CV.
- Clearly written documentation with many examples, as well as online resources which include web seminars ("webinars").
- Updates are available every six months with new algorithms, features, and performance enhancements
• The capability to system each still pictures and video. Technical support from a well-staffed, professional organization.

• A big community is available to share knowledge with free codes.

• The ability to auto-generate C code, using MATLAB Coder, for a large (and growing) subset of image processing and mathematical functions, which could then be utilized in different environments, such as embedded systems or as an aspect in different software program.

4.3 Semi-automatic method of Evaluation

The semi-automatic method of evaluation is done to obtain the results of post-arthroplasty of hip and knee. For evaluating an x-ray image automatically, plenty of image data are required to train the algorithm and also, auto-analysing of a radiographic image is very difficult that the intensity of the x-ray image or pixel values on those image cannot be used as a tool for identifying specific location or point on the image data. Moreover, the problem with the automatic method is the x-ray images, where the images taken was not standardized that, the position and placement of the patient and hence the pixel value varies for everyone, which is the major reason for non-standardization. Another important problem with automatic evaluation is intensity. Since, the measurement parameters having the same intensity and hence edge detection cannot be applied. The software knowledge and the image data are another issue for automatic evaluation. These specific points can be found easily through manual method rather than finding automatically using machine learning. The automatic analysis needs training of the algorithm using more than plenty image data, which are not available.

4.3.1 Hip Arthroplasty

It is important to evaluate the failure of hip arthroplasty earlier. There are certain parameters, which can be calculated to evaluate the result of the surgery. Some of these were explained below.
4.3.1.1 ACETABULAR INCLINATION

The acetabular inclination is defined as the angle between the articular side of the acetabular cup and the transverse axis. A line must be drawn on the medial and lateral margins of the cup and another horizontal line on the ischial tuberosity to measure the angle of intersection. The angle of intersection for a normal hip should be between $30^\circ$ and $50^\circ$. The intersection angle is below $30^\circ$ brings stable hip, but there is a possibility of limited abduction. The higher angle, where the angle of intersection is above $50^\circ$, results in dislocation in future. The angle measurement is demonstrated in the figure 4.1.\(^2\)\(^3\)

Fig-4.1 Acetabular Inclination

4.3.1.2 HORIZONTAL CENTRE OF ROTATION

The Horizontal centre of rotation is the distance from centre of the femoral head to teardrop should be bilaterally equal and is shown in the figure 4.2.\(^1\)
The ligaments which keep up the situation of the femoral head in the attachment ordinarily passes only parallel to the focal point of the femoral head. On the off chance that the surgeon neglects to put the acetabular segment in an adequately average position, these ligaments will cross average to the femoral head of rotation. If the distance between these points are not bilaterally equal, this results in the possibility of dislocation. This parameter can be calculated by drawing two lines, one from the femoral head to the acetabular tear drop of the native bone and other between the same points of prosthesis and comparing the distance between them. The lines can be drawn by marking four points manually on the image using mouse pointer.

**4.3.2 KNEE ARTHROPLASTY**

The early prediction of knee arthroplasty failure is also important like hip arthroplasty. knee arthroplasty is relatively better than hip arthroplasty on comparing the statistical data. The accuracy in measuring the parameters and the image data are the two main difficulties faced in knee arthroplasty. The parameters to evaluate the knee arthroplasty was explained below.
4.3.2.1 MECHANICAL AXIS

The mechanical axis drawn on it ought to be opposite to the knee joint line and pass through the focal point of the knee. If just a short AP film is available, the medial distal femoral angle (MDFA) and medial proximal tibial edge (MPTA) can even now be determined and is shown in the figure 4.3.[4]

Fig. 4.3 MDFA 95° and MPTA 90°

This mechanical axis should be evaluated in Anteroposterior view of the X-ray image. The MDFA can be calculated by drawing a horizontal line from the lateral meniscus to transverse ligament of the femoral component and another perpendicular line from the transverse ligament to the posterior cruciate ligament. Similarly, MPTA is calculated by drawing a horizontal line from lateral meniscus to the transverse ligament of tibia and a perpendicular line drawn from the transverse ligament to the centre of the tibia via patellar ligament. The MDFA and MPTA, which is also called as hip-knee ankle angle should be 95° and 90° respectively, if is not normal, this leads to the failure of the prosthesis.[5]
4.3.2.2 Posterior Condylar Offset (PCO) Ratio

The posterior condylar offset ratio is defined as the Ratio of the distance among the posterior condylar border and the tangent to the posterior cortex of the femoral diaphysis, and the gap between the posterior condylar border and the tangent to the anterior cortex of the femoral diaphysis as shown in the figure 4.4. The PCO ratio can be calculated from the lateral view of Radiographic image.\[^4\]

Fig-4.4 PCO Ratio

This can be achieved by drawing a line to the continuation of the distal quarter of the back femoral shaft cortex(A). A second line speaking to the continuation of the distal quarter of the front femoral shaft cortex was then drawn(B). Much of the time, the distal quarter of the femoral shaft depicts a slight foremost bow and along these lines straight lines are drawn that most firmly fit the minor bend. These two lines will in general be somewhat unique and the separations from the two lines to the most back part of the femoral condyles were estimated.
Calculations, A and B are made at the vastest piece of the back condyle and opposite to the anatomical hub of the distal quarter of the femoral shaft. The Posterior Condylar Offset Ratio was then determined by partitioning separation A by B. The PCO ratio should be equal to 0.47. This is calculated to check the restoration of condylar morphology.

### 4.4 Functions used for Evaluation

The above-mentioned parameters can be calculated by using some MATLAB functions and tools, which will be explained below.

- “filename = uigetfile(‘.dcm’,’open dicom image’)” displays a modal dialog box that lists files in the current folder and enables you to select or enter the name of a DICOM file. If the file name is valid (and the file exists), “uigetfile” returns the file name when you click Open. If you click Cancel (or the window’s close box), “uigetfile” returns 0.

- “X = dicomread(filename)” reads the image data from the compliant Digital Imaging and Communications in Medicine (DICOM) file filename. For single-frame grayscale images, X is an M-by-N array. For single-frame true-color images, X is an M-by-N-by-3 array. Multiframe images are always 4-D arrays.

- “imwrite(A, filename)” writes image data A to the file specified by filename, inferring the file format from the extension “imwrite” creates the new file in your current folder. The bit depth of the output image depends on the data type of A and the file format.

- “[x,y] = ginput(n)” enables you to identify n points from the current axes and returns their x- and y-coordinates in the x and y column vectors. Press the Return key to terminate the input before entering n points. Specify n as a positive integer.

- “line(x,y)” plots a line in the current axes using the data in vectors x and y. If either x or y, or both are matrices, then line draws multiple lines. The function cycles through colors and line styles based on the Color Order and Line Style Order properties of the axes. Unlike the plot function, line adds the line to the current axes without deleting other graphics objects or resetting axes properties.

- “dot (A, B)” returns the scalar dot product of A and B.

  If A and B are vectors, then they must have the same length.

- “n = norm(v)” returns the 2-norm or Euclidean norm of vector v.
“h = msgbox(Message, Title)” specifies the title of the message box.

“if expression
 statements
elseif expression
 statements
else
 statements
end”

“if” expression, statements, end evaluates an expression, and executes a group of statements when the expression is true. An expression is true when its result is nonempty and contains only nonzero elements (logical or real numeric). Otherwise, the expression is false. The “elseif” and else blocks are optional. The statements execute only if previous expressions in the “if...end” block are false. An if block can include multiple “elseif” blocks.

“The above-mentioned syntax and statements are obtained from MATLAB software”

4.5 Formulae used

Length between two points, x and y

Length = sqrt((x1-x2).^2+(y1-y2).^2)

Where x and y are the two points, with x1, x2 and y1, y2 are the co-ordinates of x and y.

Angle of intersection between two vectors, v1 and v2

theta =acosd (abs(dot(v1, v2))/(norm(v1) * norm(v2)) ).

Calibration factor to convert pixel values to centimetre,

Calibration Factor = v1*(21/2200); where v1 is the pixel value.
4.6 Algorithm

1. Acetabular Inclination

Explanation:

Step-1 The program starts

Step-2 Getting the DICOM image from the data folder and converting it to JPEG format for easy retrieval and operation on image.

Step-3 Converting the size of the image to 1024*1024, to view the image in large pixel for clear visualization.

Step-4 Getting four points from the user,
One, at the lower trochanters of the prosthesis
Second, at the centre point between ischial tuberosity
Third, at the face of the acetabular cup
Fourth, at the midpoint of the ischial tuberosity.

Step-5 Drawing two lines, one from first to second point, second line from third to fourth point.

Step-6 Defining the two lines as two vectors, v1 and v2

Step-7 Computing the angle between two vectors, using the formula written above and defining the value as Theta.

Step-8 conditional statement opens checking whether Theta value is lesser than 30° or greater than 50° or between two values.

Step-9 Displaying the result according to the output obtained.

Step-10 The program ends
ALGORITHM - ACETABULAR INCLINATION

START

GET DICOM IMAGE FROM THE DATABASE AND CONVERT IT INTO JPEG FORMAT

CONVERT THE SIZE OF THE IMAGE TO 1024*1024, IRRESPECTIVE OF ITS SIZE

FIRST AT THE LOWER TRONCHANTER OF THE PROSTHESIS
SECOND AT THE MID POINT BETWEEN ISCHIAL TUBEROSITY

GET FOUR MOUSE CLICKS FROM THE USER

FOURTH AT THE MID POINT BETWEEN ISCHIAL TUBEROSITY
THIRD AT THE FACE OF THE ACETABULAR CUP

DRAW TWO LINES FROM THE FOUR POINTS OBTAINED FROM THE MOUSE

DEFINE TWO VECTORS, V1 AND V2

COMPUTE THE ANGLE BETWEEN TWO VECTORS

IF THETA < 30
ELSE
A message dialog box opens,

DISPLAY "LIMITED ABDUCTION"
DISPLAY "NO RISK"
DISPLAY "RISK OF DISLOCATION"

STOP

Fig-4.5 Algorithm for calculating Acetabular Inclination
2. Horizontal Centre of Rotation

Explanation:

Step-1 The program starts

Step-2 Getting the DICOM image from the data folder and converting it to JPEG format for easy retrieval and operation on image.

Step-3 Converting the size of the image to 1024*1024, to view the image in large pixel for clear visualization.
Step-4 Getting four points from the user,
One, at the centre of the femoral head on the left side.
Second, at the acetabular tear drop of the same side
Third, at the centre of the femoral head on the right side
Fourth, at the acetabular tear drop o the right side.

Step-5 Drawing two lines, one from first to second point, second line from third to fourth point.

Step-6 Defining the distance as A and B

Step-7 Multiplying A and B with calibrating factor to convert the pixel values to lengths in centimetres.

Step-8 conditional statement opens checking whether A and B are equal.

Step-9 Displaying the result according to the output obtained.

Step-10 The program ends.

3. Posterior Condylar Offset (PCO) ratio

Explanation:

Step-1 The program starts

Step-2 Getting the DICOM image from the data folder and converting it to JPEG format for easy retrieval and operation on image.

Step-3 Converting the size of the image to 1024*1024, to view the image in large pixel for clear visualization.

Step-4 Getting four points from the user,
One, at the centre of the femoral head on the left side.
Second, at the acetabular tear drop of the same side
Third, at the centre of the femoral head on the right side
Fourth, at the acetabular tear drop o the right side.
Step-5 Drawing two lines, one from first to second point, second line from third to fourth point.

Step-6 Defining the distance as A and B

Step-7 Multiplying A and B with calibrating factor to convert the pixel values to lengths in centimetres.

Step-8 conditional statement opens checking whether A and B are equal.

Step-9 Displaying the result according to the output obtained.

Step-10 The program ends.

**ALGORITHM- POSTERIOR CONDYLAR OFFSET RATIO**

Fig-4.7 Algorithm for calculating Posterior Condylar Offset (PCO) ratio
4. Mechanical Axis

ALGORITHM - MECHANICAL AXIS

**Fig-4.8 Algorithm for calculating Mechanical Axis**

**Explanation:**

Step-1 The program starts

Step-2 Getting the DICOM image from the data folder and converting it to JPEG format for easy retrieval and operation on image.

Step-3 Converting the size of the image to 1024*1024, to view the image in large pixel for clear visualization.

Step-4 Getting four points from the user,

One, at the lateral meniscus of the femoral component

Second, at the transverse ligament

Third, at the transverse ligament

Fourth, at the posterior cruciate ligament.
Step-5 Drawing two lines, one from first to second point, second line from third to fourth point.

Step-6 Defining the two lines as two vectors, v1 and v2

Step-7 Computing the angle between two vectors, using the formula written above and defining the value as Theta1.

Step-8 Getting four points from the user,
One, at the lateral meniscus of the femoral component
Second, at the transverse ligament
Third, at the transverse ligament
Fourth, at the posterior cruciate ligament.

Step-9 Drawing two lines, one from first to second point, second line from third to fourth point.

Step-10 Defining the two lines as two vectors, v3 and v4

Step-11 Computing the angle between two vectors, using the formula written above and defining the value as Theta2.

Step-12 Adding two values, theta1 and theta2

Step-13 Conditional statement opens checking whether Theta value is equal to 185°

Step-14 Displaying the result according to the output obtained.

Step-15 The program ends.
CHAPTER-5

RESULTS OBTAINED

5.1 Hip Arthroplasty

Hip arthroplasty failures are important to evaluate earlier, as the surgery failures are relatively more and hence to take necessary steps earlier to avoid the failures. The parameters are calculated from the radiographic images, provided by the hospital and the results are displayed below.

Parameters evaluated and Results obtained

The two parameters were calculated by evaluating the radiographic images, for which the procedure was explained in the previous chapter. The obtained results are displayed below.

5.1.1 Acetabular inclination

The acetabular inclination is calculated to analyse whether the patient have the chance of dislocation or limited abduction. In our work, the type of risk, that the patient has the chance to occur later are mentioned. The procedure to take the output of the following parameters are demonstrated by a sample image shown in figure 5.1, which was followed for evaluating all the parameters.

Figure 5.1(a) Loading the DICOM image from the database
Figure 5.1(b) step-1 marking the first appropriate location in the image using the mouse pointer.

Figure 5.1(c) step-2 marking the second appropriate location in the image using the mouse pointer.
It is seen from the images shown in figure 5.1(d) that a blue line is automatically drawn at the locations, which are marked before, which is shown in the figure 5.1[(b), (c)]. This procedure is repeated in evaluating the all the parameters, which will be displayed in future.
Thus, these are the sample steps used to evaluate the parameters, in which there are minor changes in the marking of locations in other parameters, which are found and preparing to display later, but the procedure to evaluate the parameters are similar to the one, which are shown in the set of figures 5.1. The results obtained from the radiographic image and some of them are displayed in the figure 5.2.
Fig-5.2(b) Result obtained from the normal Hip image

Fig-5.2(c) Result obtained from the normal Hip image
Fig-5.2(d) Result obtained from the normal Hip image

Fig-5.2(e) Result obtained from the normal Hip image
From the image shown in figure 5.2[(a), (b), (c), (d), (e)], the output obtained as “No Risk” from the coding, which means that the acetabular inclination angle is between 30° and 50°. The output obtained from the pathological images are displayed in figure 5.3.

5.3(a) Result obtained from the pathological Hip image

From the image shown in figure 5.3(a), it is seen that, it is a double sided arthroplasty image, for the output can be evaluated on both sides and the output obtained from the left side of the hip implant infers that it is not perfect that the angle is above 50° and therefore, there are possibilities to have “Risk of dislocation” in future.

5.3(b) Result obtained from the pathological Hip image
Fig-5.3(c) Result obtained from the pathological Hip image

Fig-5.3(d) Result obtained from the pathological Hip image
It is seen from the figure 5.3[(d), (e)] that the obtained output is “No Risk”, but the image data obtained is from Pathological folder. This is because the image is considered as pathological due to some other parameters, which will be evaluated.
It is seen from the figure 5.4, it is seen that the lesser angle, which is below 30° will result in stable hip but results in limited abduction.

### 5.1.2 Horizontal centre of rotation

The horizontal centre of location was calculated, and the results are displayed in the figure 5.5 and 5.6. Centre of rotation has only the two possibilities of output, either “Risk of dislocation” or “No Risk”. The output obtained from the images are displayed in figure 5.5.

![Fig-5.5(a) Result obtained from normal Hip image](image)

![Fig-5.5(b) Result obtained from normal Hip image](image)
Fig. 5.5(c) Result obtained from normal Hip image

Fig. 5.5(d) Result obtained from normal Hip image
Fig-5.5(e) Result obtained from normal Hip image

The obtained output is “No Risk” means that the distance between femoral head and the acetabular tear drop on both the normal hip and implant side are equal.

Fig-5.6(a) Result obtained from pathology Hip image
Fig-5.6(b) Result obtained from pathology Hip image

Fig-5.6(c) Result obtained from pathology Hip image
Fig. 5.6(d) Result obtained from pathology Hip image

Fig. 5.6(e) Result obtained from pathology Hip image
It is seen from the figure 5.5[(a), (b), (c), (d), (e)] and figure 5.6[(a), (b), (c), (d), (e)] that the result obtained from the coding and the result given by the hospital are same and the pathological image, which was shown as “No Risk” in previous parameter, obtained as “Risk of Dislocation” in this parameter, which is shown in the figure 5.6[(d), (e)].

5.2 Knee Arthroplasty

Unlike Hip arthroplasty, Knee arthroplasty is 90 percentage successful. The failure in this surgery is rare and hence difficult to evaluate the radiographic images for failure. The output obtained from the image are shown below.

Parameters evaluated and Results obtained

The two parameters were determined by assessing the radiographic pictures, for which the system was clarified in the past part. The got outcomes are shown underneath.

5.2.1 Mechanical Axis

The mechanical axis is accessed by measuring the angle of intersection between lateral meniscus and the tibia on both the femoral and acetabular component and the resultant two angles will be summed and the resultant angle should be 185°. If the surgery was perfectly done using suitable implant, the result will be displayed as either “normal” or “abnormal” based on the output obtained. The obtained output is shown in the figure5.7.
Fig-5.7(b) Result obtained from normal Knee image

Fig-5.7(c) Result obtained from normal Knee image

From the figure 5.7, the results are obtained and found to be normal, which is verified with the actual image.
5.2.2 Posterior Condylar Offset (PCO) ratio

The posterior condylar offset ratio is calculated by dividing the two vectors, which are obtained by drawing two lines, one from posterior condylar border and the tangent to the posterior cortex of the femoral diaphysis and another from the posterior condylar border and
the tangent to the anterior cortex of the femoral diaphysis. The output should be equal to 0.47[+(or)-0.03]. The obtained result is shown in the figure 5.9.

Fig-5.9(a) Result obtained from the from the normal Knee image

Fig 5.9(b) Result obtained from the from the normal Knee image
Fig 5.9(c) Result obtained from the normal Knee image

Fig 5.9(d) Result obtained from the normal Knee image
It is seen from the image shown in figure 5.9, the two tangent lines are drawn, and their corresponding distance are measured and defined as two vectors and first vector is divide by the second one to obtain the required result as shown in the sample image.

Fig-5.10(a) Result obtained from the pathology Knee image

Fig-5.10(b) Result obtained from the pathology Knee image
Fig-5.10(c) Result obtained from the pathology Knee image

Fig-5.10(d) Result obtained from the pathology Knee image
From the figures shown above, it is seen that the two lines are not one above the other like the normal image shown in figure 5.9. This is because, the position of the radiograph taken is not standard and hence, this change may happen, but the tilting radiograph may not result false output, instead, the distance measurement may be tedious. For the natural knee, PCO ratio will be 0.44[±0.02] and for postoperative knee, PCO ratio will be 0.47[±0.03].
CHAPTER-6

DISCUSSION AND CONCLUSION

6.1 INERENCE OF THE RESULTS

6.1.1 Hip arthroplasty

Hence, the output was obtained for Hip Arthroplasty was shown in the previous chapter. The parameters that are evaluated in the Hip implant can help us to predict the risk of dislocation of hip implant in future. The prediction of these two parameters are particularly involved in early failures of Hip arthroplasty. The primary difficulty in calculating the output are image data. Only few image data were available, from which was obtained using MATLAB with the help of Image processing toolbox. Hip Arthroplasty has been a standout amongst the most widely recognized orthopaedic activities for as far back as 30 years. Radiography remains the pillar of imaging assessment of hip arthroplasties, with an AP pelvic radiograph the regular convention in the post usable setting-It is basic that postoperative radiographs are of high analytic quality with the patient non pivoted, prostrate, hips in augmentation and 15° inner pivot. The focal point of the x-beam shaft should be centred around the pubic symphysis to guarantee the consideration of the whole hip prosthesis also, concrete. This article gives an orderly system to radiographers to survey and assess the nature of a hip arthroplasties and features the requirement for high quality diagnostic radiography.[1] Specialists should choose their patients for arthroplasty cautiously and use inserts with long haul development and apply careful procedures that have been appeared to diminish failure rates.

6.1.2 Knee arthroplasty

The output obtained from the knee arthroplasty are involved in finding the status of the patient’s implant. The normality or abnormality of the knee implant can be inferred from the result of the work, done to evaluate the parameters. The prime aim of our ratio was to establish the normal anatomical relationship and thereby allow the assessment of restoration of this on post-operative films. Like hip arthroplasty radiographs, knee radiograph data are also difficult to obtain from the standard source. Besides, mechanical axis and PCO ratio, there are other
parameters that can be evaluated to obtain the results more precisely. A point by point investigation of radiographs of TKA helps translating of different hints in the quick postoperative radiographs. An intensive assessment of radiographs empowers choices on the following best advance, which could be simply normal development or a careful mediation. The difficulties that are faced in calculating the parameters are accuracy and precision of the location on the radiographs. At last, TKA patients require inconclusive catch up with satisfactory radiographs at each visit.

6.2 FUTURE WORK

In Hip arthroplasty, so far two parameters were evaluated, and one possibility of failure was accessed. Other possibilities include aseptic loosening, septic loosening, fracture etc can be accessed from the outputs obtained. The future work in hip arthroplasty evaluation is automatic method of evaluation, where plenty of standardized and calibrated radiographs are needed to train the algorithm, which will be used to access the result.

In knee arthroplasty, the possible future works will be a suitable algorithm to calculate the parameters automatically like automatic method of detecting edges used for surgery, from this method, the automatic detection technique can be inferred and digital radiograph of TKA was analyzed and the 3-D kinematics can be estimated. The automatic method of evaluation can be done by machine learning technique to identify the pixel location or an artificial intelligence in finding the locations, which are to be trained by the experts in the software. Calibration of plenty of knee radiographs that are used to train algorithm for automatic method of evaluation.
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