GOA Gujarat Orthopaedic Association

An affiliated chapter of INDIAN ORTHOPAEDIC ASSOCIATION | Regd. No. E/13423

GOA e-Bulletin Volume -3

Arthroplasty Edition--(July 2024)

Year 2024 - 2025

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FROM THE PRESIDENT'S DESK

Respected Seniors and dear friends,
It gives me immense pleasure in presenting the output of hard work of many super intelligent and hardworking members, who are more than willing to contribute to the cause of advancement of knowledge for the fraternity, the specialty issue dedicated to Arthroplasty!

This has been made possible by constant follow up from the chief editors Dr. Ketan Shah and Dr. ParinKantesaria along with unwavering penchant for details and perfect write up by guest editor Dr. Manish Shah. Of course each contributing author has put in their experience and knowledge gained over decades in panning down the articles and making it useful for all.

I am more than sure that this endeavor of GOA will be useful to all and will be appreciated by the members and we will be having many more contributing authors for our upcoming E- Bulletin – Journal! Please be in touch with your zonal representative for the same.

The topics for this issue have been carefully chosen by Dr. Manish Shah so that just one issue may become a compendium for life time “go to” treasure for each Orthopaedic surgeon dealing with joint replacement. From infection to various spacers to various alignment techniques to ligament balancing to PS from CR and Spino Pelvic relationship to dual mobility and defect management toDAA and Posterior approach from stalwart like Dr. Pachore; each article speaks about excellence that we, the GOA has achieved and why Gujarat is at the forefront of Orthopaedics! My sincere thanks to all the contributors for this excellent edition!

We are on constant journey of academic excellence, not only trying to promote it but proving the same also! We are constantly organizing zonal academic events and of course this bulletin- Journal is real icing on the cake. I personally invite each member of our prestigious association to come forward and contribute to the advancement of GOA!

Jai GOA!

Dr. Vijay Sata
President
Gujarat Orthopaedic Association
GOA 2024-25

FROM THE DESK OF SECRETARY

If trauma is the Amitabh Bachchan of Orthopaedics, the eternal legend and legacy ; Arthroplasty is obviously SRK, the endearing and enduring icon . Trauma like Big B offers action and solid performances as would Arthroplasty offer frenzy romanticism with thrills a la SRK.

Arthroplasty is arguably the youngest prodigy of Orthopaedic specialty and it has been a revelation and revolution. The advances and innovations in this faculty have been reassuring, rewarding and at times mind-blowing!

Having celebrated its golden jubilee, the branch has had its challenges and inventions which have had far reaching benefits, boons and blessings for the public at large. The impact of joint replacements world-wide can never be underestimated as it has redefined the laws of ageing with lifestyle of quality and independence. Arthroplasty has certainly upgraded the grace, confidence and esteem, the missing elements associated with living longer. (and loner!)

Mobility and flexibility are the goals, whilst stability and strength are the necessity. Hips and knees have been the showcases to achieve both these basic yet paradoxical needs. Maximum progress in the specialty has been focused to attain the above aspects. And of course, human kind's obsession for longevity has percolated to its invention as well. Revisions, re-revisions, efficiency of materials, refinement of techniques including minimal invasive approaches, virtual reality and robotics are the play-tools of the jigsaw . The armamentarium is ever- expanding and the aspiration as always is to be as close to natural as possible!

Dr. Manish Shah, the guest editor is a reputed and renowned Arthroplasty specialist with impeccable academic credentials. Excellence and propagation of knowledge are his forte. We are privileged to have his services and expertise for this all important issue of GOA bulletin.

Ketan Shah and Pareen Kantesaria have been the shining stars who have a solar system of their own! They are distinguished Arthroplasty surgeons in their own right. Besides, more significantly they have orchestrated this scientific philharmonic with applause and accolades for more than a year now. Their dedication and coordination have been exemplary; their passion and perseverance have been perfect.

It has been a difficult and patient task accumulating the contributions from extremely busy Arthroplasty surgeons. Yet as SRK would remark- " Kehte hain agar kisi cheez ko dil se chaho, toh puri kainaat useh tumse milane ki koshish mein lag jaati hai." This issue has truly been a labour of love. I am sure the members of GOA will have a beacon, a lighthouse of information and knowledge regarding Arthroplasty. Your positive inputs and suggestions are always appreciated. Happy reading!

Dr Ketan Thakkar
Secretary, Gujarat Orthopaedic Association
GOA 2024-25

GUEST EDITOR'S MESSAGE

In the era of ChatGPT and Ortho AI, information in any domain is becoming increasingly easy to access. The ease of access is coupled with the problem of plenty: too many VuMedi and YouTube videos, too many webinars and too many easy access PubMed articles. Effectively, reading and learning come almost to a standstill. So, when we set out to make the agenda for this GOA electronic bulletin, we decided to focus on problems which everyone faces in their day to day lives and to move a little away from the standard didactic articles but to focus on our local problems and solutions which work in our setups.

As the numbers of joint replacements increase along with the spread of the technique amongst surgeons, it is no longer something being done by an elite few. The numbers of complications have also increased, hopefully not the percentage of complications. Infection is the most common complication. For an arthroplasty surgeon, when to involve an infectious disease specialist and how to involve them is a difficult proposition. We have an excellent infectious disease specialist from Rajkot with the first article on how and when to get help of an ID specialist. It is followed by a great commentary on how to perform DAIR by an experienced surgeon from Kutch. All of us know that when that fails, using a cement spacer is the answer. But, how to make one usingmoulds and how to make one with real components are two interesting and practical articles explaining the steps so that everyone can make them.

After 2020, there has been a huge upsurge in defined knee alignments. An article has been dedicated to Kinematic alignment and its variants. We then have an essay by one of the foremost arthroplasty surgeonof Gujarat and a completely independent thinker on the various alignments and his personal views. It is supplemented by another from our sub-editor on what to make of alignments in today's arthroplasty. I am proud to say that they genuinely represent wisdom of experience and knowledge and not just information. The journey of transition from a PS surgeon to a CR surgeon from one the early specialist joint replacement surgeons is refreshing.
For the hip section, we have tried to cover the new definitions of spino pelvic relationships. For the first time, we have two female orthopedic associate professors from Ahmedabadcontributing to our bulletin. New approaches to the hip do come and go but the posterior approach remains the go to approach for most surgeons. So, we have a veteran teacher who tells us how he avoids limb length discrepancy with his standard posterior approach. Revision hips quite often need custom implants. Custom implants for arthroplasty are manufactured in Gujarat and we have one ex-President and innovator from South Gujarat teach us how to order a custom implant in Gujarat, if the situation demands.

I cannot thank the office bearers of Gujarat Orthopedic Association enough for placing trust in me and without the help of my two able sub-editors Dr Ketan Shah and Dr PareenKantesaria, this project probably would not have seen the light of day. Interruptions of summer vacations and family time did cause hardships in meeting time schedules for a few of our contributors but each and every one of them responded to our calls enthusiastically.
Wishing you a very happy reading!

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HOW DO I WANT AN ORTHOPEDIC SURGEON TO TREAT PJI

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INTRODUCTION:

Prosthetic joint infection (PJI) poses a significant challenge in orthopedic practice, leading to patient morbidity, increased healthcare costs, and potential joint failure. In this article, we delve into the indispensable role infection specialists play in the management of prosthetic joint infections. We will also discuss practical aspects on specimen collection, common mistakes we made and role of biofilm active agents in management of PJI.

Role of Infection Specialist in PJI and when to Involve ??

As soon as PJI is suspected, especially in cases of persistent pain, swelling, or limited joint function following joint replacement surgery, it's imperative to involve an infection specialist. ID specialist can help at each and every step in management pf PJI.

1) Diagnosis:

Diagnosing PJI can be complex due to the subtle and variable clinical manifestations, as well as the limitations of current diagnostic modalities. Infection specialists, meticulously review patients' medical histories, interpret laboratory results, and utilize advanced imaging techniques to differentiate between aseptic failure and infection, often identifying subtle signs that other clinicians might overlook.

e.g. middle age men with prior history of septic arthritis of right hip joint few years back, presented with fever, left knee pain and swelling. His synovial fluid showed WBC count of 80400 with 95% neutrophil. He was treated with multiple oral and IV antibiotics with marginal clinical improvement hence was referred to ID physician. After detailed history and work up he was diagnosed as inflammatory arthritis and was successfully treated with immunomodulatory agents.

2) The Multidisciplinary Approach: Managing PJI requires a multidisciplinary team approach, with infection specialists serving as key collaborators. They work closely with orthopaedic surgeons, microbiologists, pharmacists, and other healthcare professionals to formulate comprehensive treatment plans tailored to each patient's unique circumstances.

e.g. Patient with PJI with sinus track, who are vitally stable and lacks features of aggressive bacterial infection, ID physician takes detailed history, discusses surgical part and intraoperative findings with ortho colleague, and based on that data they suspect most likely organism causing infection and guide microbiologist to run special test like NTM culture.

3) Antibiotic Management and AMSP: Infection specialists are responsible for guiding antibiotic therapy in PJI management, balancing the need for effective eradication of pathogens with the imperative to minimize antimicrobial resistance and adverse effects. They employ principles of antimicrobial stewardship to optimize antibiotic selection, dosing, and duration, taking into account microbial susceptibilities, host factors, and the latest evidence-based guidelines.
e.g . A) PJI caused by MSSA , drug of choice is penicillin or first genera on of cephalosporin in spite of its sensi vity to vancomycin and linezolid. Dose of flucloxacillin goes upto 12 gm/day. B) PJI caused by Enterobacter Cloacae sensi ve to ce riaxone requires non B lactam an bio cs for prolonged

treatment even though it appears sensitive in initial culture report. The reason is SPICE group of organisms (Serratia, Providencia, Proteus vulgaris, Citrobacter, Enterobacter) can be induced to produce an AmpC gene that encodes an enzyme that cleaves the beta-lactamase group and renders it inactive.

4) Surgical Decision-making: Surgical intervention is often necessary in the management of PJI, ranging from debridement and implant retention to revision arthroplasty and staged procedures. Infection specialists collaborate closely with orthopedic surgeons to plan and execute these interventions, ensuring optimal timing and technique to maximize the likelihood of infection eradication and joint preservation. Additionally, infection control measures, such as perioperative antimicrobial prophylaxis and surgical site preparation, are meticulously implemented under the guidance of infection specialists to minimize the risk of recurrent infection.

e.g.**A)** Patient with MDR pseudomonas PJI undergoing 2 stage exchange with cement spacer ID physician can help in choosing local antibiotics, as there is no role of vancomycin or amikacin in such cases which are widely used as local antibiotics.

B) Patient with candida PJI requires prosthesis removal for successful outcome, ID physician can guide orthopaedic surgeon as well as can do good counselling of patient regarding need of prosthesis removal, which makes surgeon's job easier.

5) Complicated Cases: Despite advances in PJI management, significant challenges persist, including biofilm formation, antibiotic tolerance, and the emergence of multidrug-resistant pathogens. Infection specialists are at the forefront of research and innovation, exploring novel diagnostic tools, antimicrobial agents, and immunomodulatory therapies to address these challenges.

e.g. Treatment of a 60 year female with renal dysfunction who has PJI with multi drug resistant E.coli with intermediate sensitivity colistin with MIC 0.5 requires in depth knowledge of PK/PD parameters of drugs to achieve steady state concentration. Also it requires regular monitoring of renal function, check for drug drug interaction and procurement of novel antimicrobial agents if treatment is failing.

6) Follow-up and Long-term Care: Preventing PJI is paramount, and infection specialists play a vital role in educating both healthcare providers and patients about risk factors, preventive measures, and early recognition of infection signs. Through community outreach and professional education initiatives, infection specialists empower stakeholders to take proactive steps towards reducing the burden of PJI.

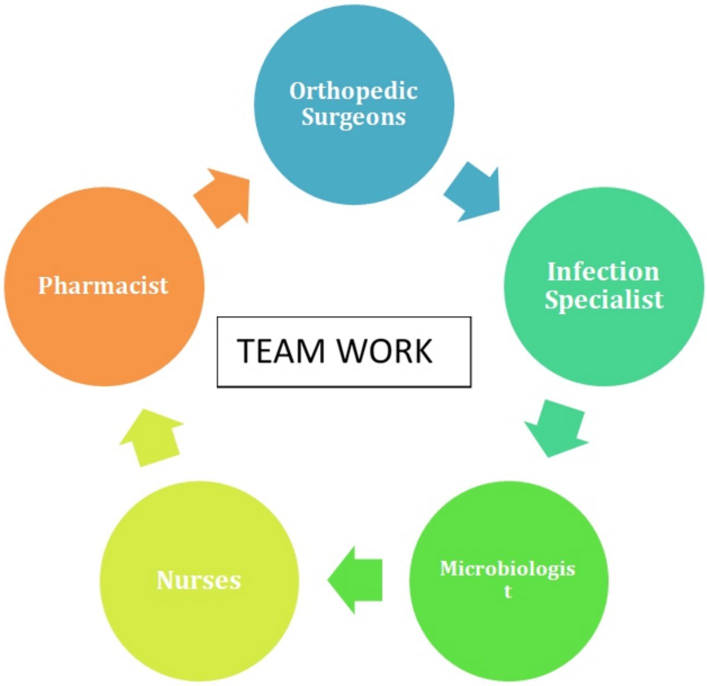
e.g. Patient with MRSA PJI who wish to continue further treatment at home, ID physician can help in assuring patient regarding need of continuing Intravenous antibiotics at home. They explain in details regarding need of CVP line, how to handle CVP line, how to prevent secondary infection, how to recognise catheter and line related infection at home.

In summary, involving an infection specialist doctor in the management of prosthetic joint infection is warranted at all stages, from diagnosis to treatment planning, surgical decision-making, and long-term follow-up care. Ideally they must involve before surgery, to plan further management. Also they can help

with pre-opera ve fitness and management of other co-morbidi es as all ID specialist are good physician also. Their specialized exper se in infec ous diseases and an microbial stewardship is instrumental in op mizing pa ent outcomes and reducing the morbidity associated with PJI.

Are there clear cut boundaries for the roles in management of prosthetic joint infection?

While there are general guidelines and recommendations regarding the roles of different healthcare professionals in the management of prosthetic joint infection (PJI), the boundaries between these roles can sometimes overlap, and the specific division of responsibilities may vary depending on factors such as institutional protocols, individual expertise, and patient-specific considerations.



Clear communication channels, interdisciplinary rounds, and regular team meetings can help clarify roles and responsibilities, address any potential conflicts or gaps in care, and optimize patient outcomes in the management of prosthetic joint infection.

What are the common mistakes made by orthopedic surgeon in management of prosthetic joint infection?

While orthopedic surgeons play a crucial role in the management of prosthetic joint infection (PJI), there are several common mistakes that can occur during the management process. Some of these mistakes include:

1) **Delay in Diagnosis:** Failing to promptly recognize and diagnose PJI can lead to delays in initiating appropriate treatment, allowing the infection to progress and potentially causing irreversible damage to the joint or surrounding tissues. Many times operating surgeon is in denial mode or not willing to accept that patient operated by him can get infection, which leads to delay in treatment and trials of antibiotics leads to Antimicrobial Resistance.

2) **Inadequate Surgical Debridement:** Inadequate debridement during surgical interven on, such as incomplete removal of infected ssue or biofilm, can leave residual pathogens and contribute to persistent or recurrent infec on.

e.g. We had a case of recurrent MRSA knee joint infec on post ACL tear surgery, even a er mul ple debridement and appropriate an bio cs, finally our ortho colleague did extensive debridement and found suture material in bone canal which was ac ng as nidus of MRSA.

3) Suboptimal Antibiotic Selections or Duration: Choosing inappropriate an bio cs or administering them for an inadequate dura on can compromise the effec veness of treatment and contribute to an microbial resistance. Addi onally, prolonged an bio c courses without clear indica ons can increase the risk of adverse effects and contribute to healthcare-associated infec ons, such as Clostridium difficile coli s.

e.g. A) using linezolid 600 once a day or Clindamycin 300 twice a day B) combining linezolid with clindamycin C) low dose vancomycin in a fear of nephrotoxicity D) meropenem 1 gm twice a day E) stopping teicoplanin early because pa ent is not affording etc.

4) Failure to Address Underlying Risk Factors: Neglecting to address underlying risk factors for PJI, such as immunosuppression, diabetes, obesity, or malnutrition, can predispose patients to recurrent infections and hinder the success of treatment efforts.

e.g. jamsen et al. reported that PJI occurred in 1.59% of THA and 2.19% of TKA patients with diabetes compared to infection rates of 0.66% and 0.48% respectively in non-diabetic patients. Some patients might need to put on insulin treatment against their will, which is only possible with patience and proper counselling, which most ID physicians have.

5) Insufficient Patient Education: Inadequate patient education regarding postoperative care, wound management, and signs of infection can result in delayed recognition of complications or failure to comply with treatment recommendations, leading to poorer outcomes.

e.g. Rifampicin should be taken empty stomach, moxifloxacin should be avoided with calcium supplements and milk products. Many patients stops antibiotics themselves due to lack of counselling on side effects of drugs, e.g. clarithromycin can cause bitter mouth, linezolid can cause tingling, numbness, amikacin can cause hearing problem etc.

6) Lack of Multidisciplinary Collaboration: Failure to involve other members of the healthcare team, such as infectious disease specialists, microbiologist, in the management of PJI can result in suboptimal treatment decisions and outcomes.

e.g. Patient with carbapenem resistant Klebsiella Pneumoniae PJI referred to ID after few days of culture report, we missed the opportunity to check sensitivity for newer drugs like ceftazidime avibactam, fosfomycin or to check for MIC value if not available, because microbiologist would have discarded culture plate.

7) Overreliance on Empirical Treatment: Relying solely on empirical antibiotic treatment without obtaining appropriate microbiological samples or considering local antimicrobial resistance patterns can lead to inappropriate therapy and treatment failure.

e.g. empiric linezolid and levofloxacin for patient with PJI.

8) Inadequate Infection Prevention Measures: Failing to implement adequate infection prevention measures, such as proper surgical technique, perioperative antimicrobial prophylaxis, and sterile instrumentation, can increase the risk of surgical site infections and PJI.

e.g. non tuberculous mycobacteria have high level of resistance to glutaraldehyde(cidex) andsterilization of instrument with it might lead to NTM outbreak.

9) Poor Communication and Documentation: Inadequate communication among members of the healthcare team and insufficient documentation of treatment decisions, interventions, and follow-up plans can result in fragmented care, medical errors, and suboptimal outcomes for patients.

e.g. A) many pa ents have huge dilemma regarding dura on of treatment in PJI, when we explain them that treatment will last in weeks they seems very confused. B) lack of explanation about side effects of medica on like linezolid induced painful neuropathy

By being aware of these common mistakes and implemen ng strategies to address them, orthopedic surgeons can improve the quality of care and outcomes for patients with prosthetic joint infection. Collabora on with other healthcare professionals and adherence to evidence-based guidelines are essential for optimizing the management of PJI.

How and when to order culture in management of prosthetic joint infection and how to avoid no growth phenomenon?

Ordering cultures is a crucial step in the management of prosthetic joint infection (PJI) and should be done judiciously to maximize diagnostic yield and guide treatment decisions. A study done at tertiary care hospital in india by Dr pragna rani and colleagues found 57.6% culture positivity after extended culture methods among orthopaedic surgery patients.

Here's how and when to order cultures in the management of PJI:

1) Clinical Suspicion: Cultures should be ordered when there is a clinical suspicion of prosthetic joint infection based on symptoms such as persistent pain, swelling, erythema, warmth, or drainage from the surgical site, especially if these symptoms develop weeks to months after joint replacement surgery.

2) Involve Infection Specialist Preope: As detailed history is the first procedure. history regarding comorbid condition, immune status, travel history, occupation is very important in ordering particular tests and culture reports. Also it is very crucial to guide microbiologist to look for particular pathogens based on patient's detailed history.

e.g. patient with uncontrolled DM from Ratnagiri with chronic osteomyelitis of left tibia which was treated as Tuberculosis based on granuloma mentioned in histopathology report, was finally diagnosed as melioidosis after ID physician suspected it and asked microbiologist to look for it.

3) Antibiotic free period: Cultures should be sent before the initiation of antibiotics to maximize the likelihood of isolating causative pathogens. In patient with chronic infections who are stable hemodynamically ideal antibiotic free period is 14 -21 days. study done by david murphy et al found antibiotics administration before collecting bacterial cultures reduces positivity rate with in minutes.

4) Aviod using swab for cultures: sending swab from sinus tract or nonhealing ulcer could pick up colonizer and treatment of it might result in mere wasting of money and time, failure of treatment and development of drug resistance. Study done by S. Tedeschi found that the cultures of a superficial ulcer swab are not useful in either the diagnosis of a superinfection or the prediction of the role of involved micro-organisms. So best samples to send for cultures are intra ope tissue or pus and Joint aspiration. Aspiration should be performed using aseptic technique, ideally under fluoroscopic or ultrasound guidance, to minimize the risk of contamination.

5) Multiple Site Cultures: In cases of suspected PJI, cultures should be obtained from multiple sites. Ideal sample sites are superficial to implant, deep to implant over bone, scraping of biofilm, nail entry site, medullary reaming. In PJI following TKR sampling should be done from synovium, tibial component, femoral component and posterior capsule. Different instrument should be used for each sample.

6) Specimen Handling: Tissue and pus should be taken in sterile leak proof container and should be labelled properly regarding site of collection. E.g. intramedullary pus, granulation tissue from thigh, scraping from nail etc. Liquid samples like synovial fluid, pus, deep liquefied hematoma should be sent in aerobic and anaerobic blood culture bottles. Synovial fluid should be collected in EDTA bulb for cell count and in red(plain) tube for chemical properties. It is essential to communicate to the laboratory that the specimen is for culture and to provide relevant clinical information, including suspicion of PJI and any previous antibiotic therapy.

7) Culture Techniques: Cultures should be performed using both aerobic and anaerobic media to maximize the likelihood of isolating diverse pathogens. Additional culture methods, such as sonication of explanted prosthetic components, may be employed in cases of suspected biofilm-associated infections. Further tests like fungal culture, TB genXpert ultra, TB MGIT culture, myco F lytic culture should be ordered after consultation with ID specialist. Molecular tests like biofire BJI panel is a novel test which identifies 29 bacteria, 2 fungi and 8 resistance genes with in hours.

8) Microbiological Analysis: Once cultures are obtained, microbiological analysis should include Gram staining, culture, and identification of isolates. Susceptibility testing should be performed to guide antibiotic selection, particularly in cases of multidrug-resistant organisms.

9) Interpretation and Clinical Correlation: Culture results should be interpreted in the context of clinical findings, imaging studies, and other diagnostic tests. Positive culture results, along with clinical evidence of infection, support the diagnosis of PJI and guide antimicrobial therapy selectio

By following these principles and guidelines, healthcare providers can optimize the diagnostic accuracy of cultures in the management of prosthetic joint infection and tailor treatment strategies to individual patients' needs. Multiple study shows that by following structured tissue sampling protocol with help of ID specialist and microbiologist diagnostic yield can improve upto 70 to 90% .

When to start antibiotics in management of prosthetic joint infection?

The decision to start antibiotics in the management of prosthetic joint infection (PJI) should be based on clinical suspicion, supported by diagnostic evaluation, and guided by the likelihood of infection, the severity of symptoms, and the urgency of treatment. Here are some general principles to consider:

Clinical Suspicion: when there is a strong clinical suspicion of PJI based on symptoms such as persistent pain, swelling, erythema, warmth, or drainage from the surgical site, antibiotic should be initiated after diagnostic work up and after sending cultures from joint aspiration or specimen from surgical debridement. We should avoid using ore-operative antibiotics in such case scenario.

Severity of Infection: In cases of severe PJI with systemic symptoms such as fever, chills, or signs of sepsis, broad spectrum antibiotics should be initiated promptly after sending blood cultures to control the infection and stabilize the patient's condition.

Follow-up and Monitoring: Close monitoring of the patient's clinical response to antibiotic therapy is essential. If there is no improvement or if the infection worsens despite appropriate antibiotic therapy, reassessment and adjustment of the treatment plan may be necessary.

Role of newer biofilm piercing antibiotics in management of prosthetic joint infection?

Periprosthetic joint infection is characterized by the formation of biofilm on the implanted foreign body. Biofilm consists of bacteria (in some cases yeasts) surrounded by an extracellular matrix and offers a protective environment for the microorganisms present . These microorganisms enter a dormant state and, consequently, antimicrobial agents cannot exert the desired effect on these microorganisms. The protective environment that biofilm offers matures over a course of days to weeks, implying that the duration for which an infection has existed is an important determinant of the outcome of antibiotic treatment.

The inherent properties of biofilm have led to the emergence of several principles for the treatment of PJI. **1)** surgical source control with extensive debridement is an essential part of treatment. Obtaining source control for biofilm infections presenting in an early stage (generally acute infections with an immature biofilm) may be restricted to surgical debridement with implant retention (DAIR). Achieving source control for chronic biofilm infections (generally assumed to be in existence for more than 3 to 4 weeks) often requires complete removal of the foreign body due to the presence of a mature biofilm. **2)** select antimicrobials with activity within a biofilm are needed. **3)** The duration of antimicrobial therapy is prolonged and often extends to a treatment duration of three months, depending on the surgical strategy.

Newer biofilm-penetrating antibiotics have shown potential advantages in eradicating biofilm-associated pathogens and improving clinical outcomes in patients with PJI. Here are some key aspects of their role:

1) Biofilm Disruption: Biofilm-penetrating antibiotics have demonstrated enhanced ability to penetrate the extracellular matrix of bacterial biofilms, where conventional antibiotics may be less effective due to limited penetration. By disrupting the biofilm structure, these antibiotics can expose bacteria to higher concentrations of antimicrobial agents, enhancing their bactericidal activity.

2) Increased Efficacy: Studies have shown that biofilm-penetrating antibiotics, such as daptomycin, linezolid, rifampin, and fosfomycin, may be more effective than traditional antibiotics in eradicating biofilm-associated pathogens commonly implicated in PJI, including Staphylococcus aureus, coagulase-negative staphylococci, and Enterococcus species. Addition of Fluoroquinolones show good in vitro activity against biofilms produced by certain Gram-negative organisms like Pseudomonas aeruginosa, Escherichia coli and Stenotrophomonas maltophilia. In addition, observational studies reported good outcomes using ciprofloxacin, and is therefore, still the first-line antibiotic treatment for PJIs caused by Gram-negatives

3) Combination Therapy: Biofilm-penetrating antibiotics are often used in combination with other antimicrobial agents to optimize treatment outcomes and minimize the risk of resistance development.

4) Implant Salvage: In cases where implant retention is desirable, biofilm-penetrating antibiotics may facilitate successful implant salvage by eradicating biofilm-associated pathogens and preventing recurrent infection. This can help preserve joint function and avoid the need for extensive surgical revision or explantation.

5) Chronic and Recurrent Infections: These antibiotics can target persistent infection reservoirs and improve the likelihood of infection clearance.

6) Research and Innovation: Novel agents, such as antimicrobial peptides, nanoparticles, and biofilm disruptors, are being investigated for their potential to target biofilm-associated pathogens and improve treatment outcomes.

The management of prosthetic joint infections exemplifies the necessity for a multidisciplinary approach in modern medicine. By combining the infection specialist's expertise in microbial management with the orthopedic surgeon's surgical skills, healthcare teams can significantly improve patient outcomes. This collaborative model serves as a blueprint for treating complex infections, ultimately enhancing patient care and recovery.

HOW DO I DO DAIR: DEBRIDEMENT, ANTIBIOTICS AND IMPLANT RETENTION

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BACKGROUND

Periprosthetic joint infection (PJI) remains one of the most common causes of early revision surgery for total hip and knee arthroplasty (THA, TKA). While there are several different surgical options for the management of PJI, this article will focus specifically on the indications, techniques, and outcomes of mechanical and chemical debridement, commonly referred to as debridement, antibiotics, and implant retention (DAIR).

INDICATIONS AND TIMING

- Acute Postoperative infection, less than 4 weeks duration with stable functioning implants.
- Acute Hematogenous infection, less than 4 weeks duration with stable functioning implants.
- Patients medically unfit for 2 stage revision – DAIR with chronic antibiotic suppression – relative indication.

While an acute PJI is not a surgical emergency, it should be dealt with urgently once the patient is medically optimized.

CONTRAINDICATIONS OF DAIR

- Infections more than 4 weeks duration
- Infections with duration range of 2 to 4 weeks with resistant organisms to all antibiotics, specifically gram negative.
- Infections with discharging sinus
- Unstable Joint / Grossly mal-aligned Joint / Loose implants

PREOPERATIVE ARTHROCENTESIS

Before initiating systemic antibiotics, it is mandatory to aspirate the joint fluid and try to find the causative organism. Gram stain, routine examination of fluid, as well as bacterial and fungal cultures are to be done. Sensitivity of organism if found, helps in intraoperative antibiotic delivery systems like antibiotics impregnated cement beads and also for postoperative antibiotic protocols.

Extended cultures for 2 to 3 weeks, TB-PCR and newer techniques like NGS (Next Generation Sequencing) can be tried in cases where routine cultures are negative.

TECHNICAL CONSIDERATIONS FOR DAIR

The prior incision is most frequently utilized. DAIR requires thorough debridement with a meticulous technique to maximize bacterial bioburden eradication. Multiple tissue samples are taken and sent for bacterial and fungal cultures. The integrity of implants should be assessed to ensure fixation to bone. Irrigation can be augmented with various antiseptics or antibiotics,but mechanical debridement, with a meticulous synovectomy and soft tissue debridement along with the exchange of modular components, when possible, remains the critical component of the procedure.

Drapes and Surgical Setup

Disposable drapes and gowns are preferred. Two trolleys for 'Clean' and 'Dirty' setup is used. Once the debridement and irrigation process is over, the 'Dirty' trolley is moved out of the surgical field. All drapes, gowns, gloves, and instruments should be exchanged for clean ones after the debridement and irrigation, and prior to the implantation of the new modular components. This theoretically decreases contamination from the infected surgical site. The impact of changing drapes during DAIR has not been directly investigated and therefore may be left to the surgeon's discretion – but in general is followed at most of the centers.

Exchange of Modular Implants

Exchanging modular components for new ones is an important factor in reducing bacterial load. Not only does exchanging polyethylene components or a modular head remove any biofilm on that material, but it also allows for better access to otherwise difficult-to-reach areas of the joint. Removing the polyethylene in a TKA provides improved visualization into the posterior aspect of the knee for a complete synovectomy. Improved visualization will allow for a more thorough debridement overall. Many a times an insert of one size up will be used in TKA.

Several studies supported the exchange of modular components as one method to reduce the rate of PJI recurrence [1, 2, 3, 4, 5]. A meta-analysis of 39 retrospective studies demonstrated a higher success rate (73.9% vs. 60.7%) in THA treated for PJI who underwent exchange of modular components [6]. Overall, the success rate of the DAIR procedure is quite variable, but this is one factor that appears to decrease the risk of failure and should be performed. The International Consensus Meeting (ICM) on Orthopedic Infections recommends modular component exchange with moderate strength of evidence.

Mechanical Debridement

The adequacy of mechanical debridement is perhaps the most important factor in the success of the DAIR procedure, but arguably the hardest to study. Techniques are surgeon-specific and perhaps contribute to the large variability in the literature of the success of DAIR. Regardless, removal of all devitalized and infected tissues as well as inflamed and hypertrophic synovium is recommended. A radical synovectomy may be performed to eliminate all infected tissue around the joint. At times it may be difficult to distinguish between infected and non-infected tissue. Usually, a tissue plane can be developed between more normal tissue and the infected and inflamed synovium. In principle, all non-vital tissue should be debrided including synovium and thickened scar tissue. Thus, a radical synovectomy is performed and in TKA's, careful attention is given to the suprapatellar pouch and medial and lateral gutters. The posterior aspect of the knee is debrided using a scoop to remove thickened, inflamed synovium. Additionally, the deep aspect of the extensor mechanism should also be debrided, along with resection of the soft tissue "meniscus" namely the thick layer of soft tissue that typically forms around the periphery of the patellar implant. All retained nonmodular components should be thoroughly scrubbed with a sterile brush, implant bone interface curetted and then irrigated with an antimicrobial/antiseptic solution and sterile saline.

This part of the surgery is the most crucial aspect of the surgery and should be given sufficient time. Typically, the total procedure takes as much or many times even more than the index primary procedure. Whenever possible a 'Senior' surgeon should be available to do the procedure and should not be left to the 'Juniors'. Multiple samples of tissues are taken and sent for cultures and for histopathological examination.

Irrigation

Sterile saline irrigation is generously used throughout the surgery to mechanically remove contaminants from the surgical field. A minimum of 5 to 6 L is mandatory, and studies have supported volumes upto 9L also. Pulsatile lavage is used routinely for the same, though few studies don't deem it compulsory.

The ideal irrigation type, volume, and pressure have not been established. The ICM gave a strong consensus recommendation by the super majority that 6–9 L of irrigation appears to be sufficient.

Antiseptic Irrigation Solutions

Antiseptic irrigation solutions have emerged as a tool to aid in reducing the risk of infection in aseptic arthroplasty surgeries. Most of the current arthroplasty literature focuses on dilute povidone-iodine and chlorhexidine in the setting of primary and revision total joint arthroplasty. In vitro studies suggest that many antiseptic solutions including povidone-iodine, chlorhexidine, hydrogen peroxide and acetic acid may be useful in the management of PJI. There is some benefit for using multiple solutions to treat known PJI in a DAIR procedure based on the properties of each agent.

At our Centre, Povidone-Iodine solution mixed with a few drops of Hydrogen Peroxide and Saline irrigations are used intermittently for no less than 6 cycles. Note is to be made that Povidone-Iodine mixed with Hydrogen Peroxide is left for at least 2 minutes before irrigating with Saline solution. We add 2ml of Gentamicin to 1L saline for all irrigation and the same we also follow in Primary arthroplasties.

Local Antibiotics Delivery Systems

In recent times, whenever possible we use Stimulan beads mixed with antibiotics before final arthrotomy closure. If sensitivity of the organism is available then the antibiotics are used accordingly, and if not then Vancomycin along with Colistin is used. Drains are not used, or if needed then used only intermittently for 12 hours.

ALTERNATIVE INRAOPERATIVE ADJUNCTS

Methylene Blue

Methylene blue is a cationic dye that can bind to eukaryotic cells and bacterial biofilms. Upon binding, the dye will stain these structures and can be a useful tool in guiding debridement of biofilms. In vitro models have demonstrated successful staining of Staphylococcus epidermis biofilms on orthopedic implants. More recently, a study on the clinical application of methylene blue has demonstrated improved identification of staphylococcal biofilms in a comparison of stained vs. unstained tissue in cases of PJI [7]. In this study, methylene blue was diluted to a concentration of 0.1% and instilled for 60 s over the surgical site after the removal of the polyethylene. This may be a useful adjunct in DAIR to maximize the eradication of biofilms.

Intraosseous Antibiotics

IO vancomycin was ini ally studied in the se ng of primary and revision TKA prophylaxis. Studies have demonstrated that IO vancomycin administra on achieves drama cally higher ssue concentra ons than intravenous administra on in primary TKAs [8], revision TKAs [9], and even in cases of limited tourniquet usage [10]. Administering IO an bio cs can be performed rela vely quickly and safely into the proximal bia. Current protocols recommend infusing 500 g of vancomycin diluted with 140 mL of normal saline into the proximal bia over a period of 1–2 min a er infla on of a thigh tourniquet [11].

POSTOPERATIVE CONSIDERATIONS

Antibiotic Therapy

There is a large variation in the literature regarding the length of treatment, route of administration, and type of antimicrobial therapy for patients after DAIR. Antibiotic therapy should be tailored based on intraoperative cultures and susceptibilities. Empiric treatment may be initiated once cultures are taken and should be based on the patient's risk factors and infection history as well as the hospital's organism patterns. The duration and type of antimicrobial therapy depend on the patient profile and organism.

IV antibiotics should be administered for the first 10–14 days, followed by a transition to oral antibiotics for the remainder of the therapy for at least 10 to 12 weeks (about 3 months). Co-management with an infectious disease specialist to help dictate antibiotic therapy and monitor appropriate dosing and laboratory markers is recommended. The ICM gives a moderate strength recommendation for a minimum of 6 weeks of antibiotic therapy after DAIR. Response is monitored periodically by hematological inflammatory markers, and to look for potential side effects of antibiotics.

Factors Associated with Successful Outcome

There are several factors that have been associated with successful treatment of acute PJI with DAIR. The exchange of modular components, particularly polyethylene, has been shown to increase the success rate of DAIR. Previously, studies have shown that bacteria adhere to materials with rougher surface microtopography, such as polyethylene. The timing of surgical debridement has been shown to result in greater success if done within seven days or less from the onset of symptoms. After the procedure, the addition of rifampin in staphylococcal PJI or fluoroquinolones in Gram-negative PJI has been supported.

Risk Factors Associated with Failure of DAIR

There are certain host-related factors that are important to consider prior to performing DAIR. Rheumatoid arthritis has been shown to be a risk factor for failure of DAIR. Age is associated with worse outcomes, especially in patients older than 80 years. Some studies showed a higher rate of failure in male sex as well. Chronic renal failure, liver cirrhosis, and chronic obstructive pulmonary disease are also associated with higher rates of failure. Naturally, given the relative immunocompromising nature of these co-morbidities, it makes intuitive sense that individuals with these conditions would be at a higher risk of failure. When a patient presents with significantly elevated inflammatory markers, such as a C-Reactive Protein > 115 mg/L, there is also a significantly higher rate of failure. Moreover, patients with acute PJI in the setting of arthroplasty for the treatment of fracture or revision arthroplasty have higher failure rates after DAIR. Finally, certain pathogens portend a worse prognosis. Staphylococcus aureus and Enterococci spp. have higher failure rates than other pathogens.

Failure and Treatment Options

Overall, a er treatment failure of a DAIR, a two-stage revision is often the next logical choice. A repeat DAIR after the failure of 1st DAIR is not recommended as it suggests the failure of primary DAIR itself. Based on currently available evidence, DAIR does not appear to compromise the results of a subsequent two-stage exchange. Earlier studies suggested higher failure rates of a two-stage exchange a er DAIR, however, subsequent studies do not demonstrate an increase in failure rates.

Special Circumstances

A unique group where DAIR can addi onally be considered is in the treatment of acute or chronic PJI with extensive implant instrumenta on. In select cases, pa ents may have such extensive instrumenta on that removal of the implants would compromise limb func on or risk amputa on. In these scenarios, DAIR may be considered in addi on to chronic, suppressive an bio c therapy.

CONCLUSION

DAIR is an effective treatment option for the management of an acute postoperative or hematogenous PJI in appropriately selected patients with well-fixed implants. There are many considerations the treating surgeon should be aware of including preoperative factors, the need for a meticulous intraoperative debridement technique, and appropriate postoperative antibiotic management.

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HOW DO I MAKE MOBILE SPACERS WITH MOLD

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AHMEDABAD

Globally over 10 percent population is above 65 and its on rise. For same reasons end stage arthritis and its most common treatment TKA is also on rise (1)

Infection in Total knee arthroplasty (TKA) is a devastating complication. Over the years our understanding of this field (prosthetic joint infection) has evolved, but the general prevalence of infection still remains between 0.5 to 2 % (2).

The three most common treatment method for PJI is DAIR (Debridement, antibiotics and implant retention),Two stage revision and Single stage revision. Out of which Two stage remains gold standard because of its consistent results(3).

The Two stage approach was popularized by Dr Insall in 1980s and was further modified in 1990s.It involves debridement of infected synovium, removal of the prosthesis, and inserting a temporary cement spacer (4). The mainstay of this procedure is antibiotic cement spacer.

Cement spacer are of two types, static and articulating. The articulating spacer is preferred over static spacer because its functional superiority and better range of movement (5,6). However static spacers is still indicated in patients with severe bone loss , collateral ligament insufficiency and deficient extensor mechanism (7).

There are four ways how surgeon can use a articulating cement spacers. Each has its merits and demerits.

A B C

A) Hand made cement spacer B) Ready made cement spacer C) Disposable surgical mold

1) Handmade cement spacers – Handmade cement spacers are not used commonly now a days. The design is coarse and not reproducible. Stability is questionable. Dislocation and dislodgement are the two most common complications. However it's cheap and antibiotics can be mixed as per the organism.

2) Ready made cement spacers – Very commonly used spacers. They are factory made and antibiotics (E.g. Gentamycin or Vancomycin) is premixed. The shape is good and because of conformity the stability is also good. However there are some disadvantages. Because the antibiotics are premixed it

can't be organism specific E.g. vancomycin for a gram negative bacteria or gentamycin in a MDR organism. Another issue is that the antibiotic are of low dose E.g. maximum of 2g of vancomycin or gentamycin). Most of the preformed cement spacers does not have keel in tibial component making it prone for dislodgement.

3) Disposable surgical molds – Probably these are the most commonly used spacers because of its advantages. Good design , keeled tibia , good stability and option for organism specific antibiotic mixing. The only disadvantage here is its high cost.

4) Reusable metal mold (ITAS) –Interlude Temporary Arthroplasty System (ITAS) is one such reusable metal mold which is designed by Dr Yuvraj Lakum (MS Ortho), Wishbone orthopedics Ahmedabad . The mold is designed in such a way that it fulfills all the needs of arthroplasty surgeon for a particular PJI case. It has good design, patella friendly groove in femur and available in S, M and L sizes. It has keeled tibia for better implant grip. The gap management can be done by using available tibial component sizes which ranges from 10 mm to 27.5mm. It also has option of adding a rod to tibia or femur in cases with defect. Antibiotics or antifungals can be mixed as per the organism and its cost-effective and has low carbon footprint as its reusable in nature.

A B

A) ITAS Femur Mold B) ITAS Tibia Mold

Operative procedure

Any stage 1 surgery has 3 critical steps to be followed . 1) Debridement 2) implant removal 3) Antibiotic cement spacer insertion.

Step 1 Debridement

Meticulous removal of whole synovial lining including the one in posterior compartment is an extremely important step in the mechanical debridement of soft tissue. Try to avoid leaving any islands of synovium in between . One can use methylene blue dye to stain the synovium before removing it . 3% Acetic acid is used as a method of chemical debridement with exposure time of 21 minutes after implant removal. The exposed bone after the implant removal can be debrided by using a high speed burr or saw. Approx 1-2mm of bone can be removed.

Step 2 Implant removal

Implant removal should be a gentle procedure. All the care should be taken to avoid any injury to femoral condyles and proximal part of tibia for stability of spacer and for future revision. One should have flexible osteotomes and small oscillating saw blade in the armamentarium.

Step 3 Antibiotic cement spacer

Which antibiotic ??

Organism specific heat stable antibiotics should be used when organism in known. Follow Rule of 10 % . As a general rule 4 g antibiotic can be mixed in a 40 g (single batch) cement. Avoid liquid antibiotics as far as possible(e.g Gentamycin). Choice of antibiotics should also be based on age of the patient and comorbidities.

Gram positive organisms – Vancomycin . Per batch 4 g . In total maximum 8 gm in one surgery. Most gram positive organisms are vancomycin sensitive (except VRE). Be careful in using vancomycin in elderly patients and patients with renal compromise.

Gram Negative organisms – Meropenem. Per batch 4 g . In total maximum 8 gm in one surgery. Most gram negative organisms are Meropenam sensitive (except MDR or XDR organism). It Can be used in elderly patients and is relatively kidney safe.

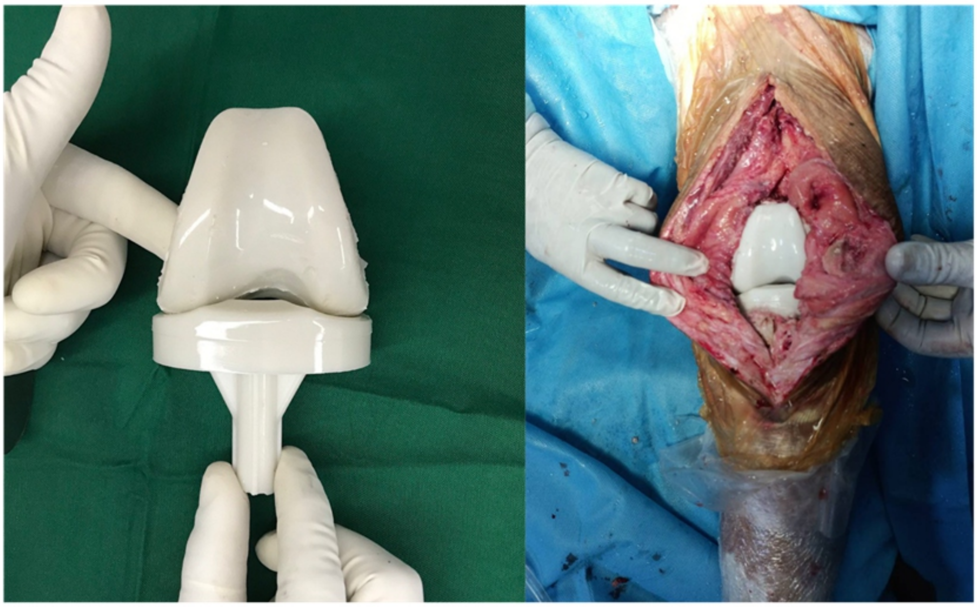
MDR/ XDR Gram Negative – colistin. Per batch 4.5 MIU. In total maximum 9 MIU in one surgery. Avoid using colistin in elderly patients and patients with kidney issues. If compulsory then use it as per advice of ID specialist and nephrologist

Culture negative – VCA . vancomycin 2g . colistin 4.5 MIU. Amphotericin 2g per batch of cement.

Making of cement spacer :

Decide the size of the femur and tibia based on the templates given. ITAS comes in small, medium and Large sizes . Decide the thickness of tibial component based on the flexion and extension gap. Decide the need of extension rod based on bone loss.

Once the decision is made use the particular mold to make femur and tibia. 1 batch of antibiotic mixed cement for femur and 1 -2 batch of antibiotic mixed cement for tibia as per the thickness is required. Pour the cement in the mold and wait for curing. Once the cement is set remove the components from mold.



A B

A) ITAS Femur and Tibia B) ITAS Implanted

One can do a dry trailing before the final cementing to see the stability of component. Once satisfied with the trial, final components can be loosely cemented by using 1 packet of antibiotic cement.

A B C

ITAS in special situations.
A) ITAS with femur and tibia rod with major femur and tibia bone loss B) ITAS with tibia rod with Steinmen pin as a scaffold C) ITAS with humerus interlock for PJI with tibia fracture

ITAS can be used with femur and tibial rods in special situation with extensive bone loss or as a spacer in revision total knee replacement with rods. ITAS can also be used along with interlock nail in a fracture situation.

In most of the patients range of movement exercise can be started on next day and are made to walk with full weight on 2nd or 3rd day with or without brace. At around 1 month spacer behaves like an arthroplasty with almost all patient doing all functional activities and achieves above 90 degree flexion.

During the revision the removal of spacer is easy and comes out in toto. Because of good range of movement it revision does not require extensile approaches or TT osteotomy. Because the spacer is quite stable it does not cause further bone erosion.

An inhouse study was conducted by authors in January 2024. 250cases of ITAS were done by 70 surgeons over last 2.5 years. Google form of questionnairewas sent to them and response recorded. Infection eradication was 87% . Average range of movement achieved was 100 degree. Average KSS was 90. Average revision time was around 4 months with some patient walking on spacer for more than 1 year without breakage. 1 case of dislocation because of dysfunctional LCL which was converted to static spacer. There was no case of spacer fracture or spacer dislodgement.

	Hand made	Industry premade	Disposable spacer mould	ITAS
Good design	No	Yes	Yes	Yes
Stability of components	No	Yes	Yes	Yes
Ease of insertion	Yes	Yes	Yes	Yes
Use of desired antibiotic in cement	Yes	No	Yes	Yes
Balancing and gap management	Yes ...	No	Yes	Yes
Ease of removal	Yes	Yes	Yes	Yes
Cost	Not much	Reasonable	Expensive	Negligible

Overall reusable metal molds like ITAS has all what an arthroplasty surgeon needs and its also cost effective to patients with low carbon footprint.

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CEMENT SPACER

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INTRODUCTION:

As there is an increase in number of knee replacements there is also increase in periprosthetic joint infections (PJI). Main surgical options for the PJI are debridement, one stage revision or Two-stage revision. Two-stage revision has been a gold standard treatment modality for prosthetic joint infection.1

It consists of removal of the implant followed by debridement and implantation of an antibiotic spacer. This delivers local antibiotic in a much higher concentration than the MIC, which leads to elimination of infection. There are mainly two types of antibiotic spacers exists, Static and Dynamic. Static spacers are useful and cost effective but they cause joint stiffness, fractures, and dislocations. So they are useful if arthrodesis is planned as a definitive procedure. Articulating spacers has advantage of maintaining the range of motion of the joint and early mobilizing the patient. They also maintain the muscle function. Bone loss is less leading to better functional outcome. Articulating spacers are available commercially as molds or pre-made antibiotic spacers. But they are costly, implant dimensions are fixed and antibiotic choice and dose is prefixed. Hofmann AA et al., in 1995 first described the use of real components by autoclaving the explanted components and using them with antibiotic cement. This gives us freedom to use antibiotic we require and in the dose we require. Many studies have shown good results using the similar technique.3, 4 since the cost of knee implant has been controlled we have started using a new implant with the cement spacer. This gives us freedom to use the type of antibiotic and in the dose we require. And it also carries all other advantages of articulating spacer as described. We have used a modification of the Hofmann technique for the preparation of an articulating, stemmed, antibiotic-impregnated cement spacer using new real components for stage 1 of 2-stage revision total knee replacement. We call it stage 1.5 as with the use of this new implant it serves both purposes of delivering high concentration antibiotic locally as well keeping the joint mobile and supple.

2.Technique

The knee joint was exposed through a standard approach. A sinus tract if present is included in the incision and complete excision of the tract is done. Radical debridement, removal of implants, and lavage were performed. Deep tissue samples were collected from different sites and sent for culture and sensitivity with each sample in a separate sterile jar. The removed implants served as a guide for sizing. We selected the appropriate implant size by either upsizing or downsizing the removed implant. For sizing of the tibial poly, 3–4 mm was added to the thickness of the removed component for the tibial tray thickness. Compensation for ligamentous laxity and bony defects were noted. The trial reduction was performed with trial components.

A new Posterior Stabilized (PS) femoral component and a new PS tibial poly were used. A 5.5 mm drill bit was used to drill in the center of the post of the tibial poly from the bottom without breaking out at the top. An Ilizarov rod (core diameter 6 mm) of the desired length for the tibial stem was screwed into the poly to make a composite construct (Fig. 1). The other end was fixed with two nuts to lock them only if the desired diameter of the rod was 10 mm or higher. If the desired diameter of the rod was less than 10 mm, no locking nuts were used at the other end.

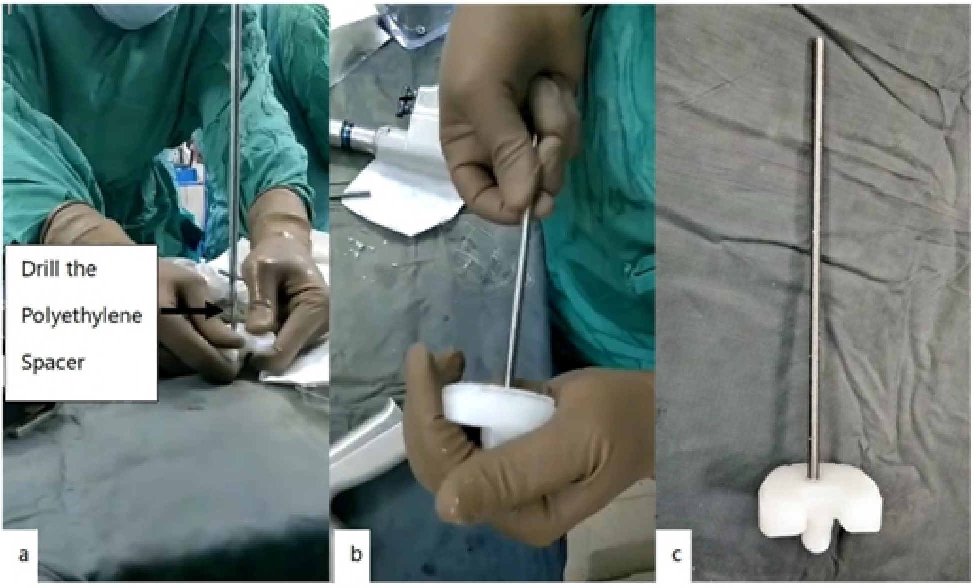

Fig. 1. Preparation of the Tibial Component. (a) Use a 5.5 mm drill bit to drill the base of the polyethylene spacer. Only drill the near surface. (b), (c) Tighten the Ilizarov rod to the base of the polyethylene spacer to make the tibial component of the spacer.

The femoral stem was prepared of the desired length and diameter depending on the diameter of the last reamer used and its depth. Two (one for femur stem and one for tibial stem) pre-sterile, endotracheal tubes of desired diameters were opened and split open. An Ilizarov rod of the desired length of the femoral stem was taken. A female hinge was used at one end. The other end was fixed with two nuts as described earlier. The rod was placed inside the split open endotracheal tube (Fig. 2)

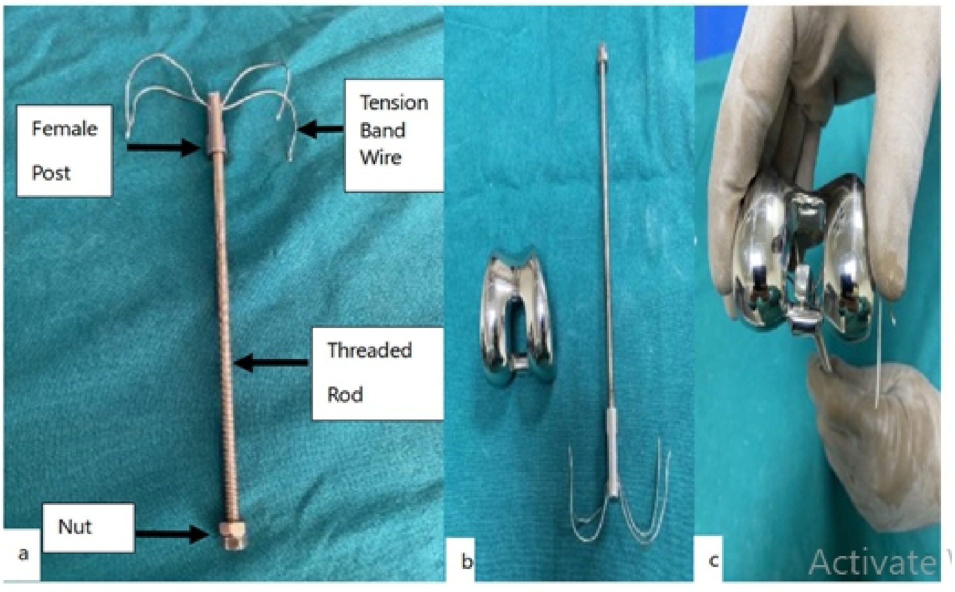

Fig. 2. Preparation of the Femoral Component. (a) The femoral intra-medullary component is prepared by attaching a female post to one end of an Ilizarov rod and two 10 mm nuts to the other end. Pass TBW wires through the eye of the female post.

(b,c) Take new femoral implant and place it over the intra-medullary femoral component.

A standard 40 gm. cement pack was taken and mixed. Desired antibiotics, according to previous culture sensitivity reports of the organism identified were added after the initial polymerization had occurred. 4 gm. of sterile Vancomycin powder, 9 million IU of sterile Colistin powder, and 10 ml of sterile Tobramycin liquid (40 mg per ml) were added this stage per 40 gm. cement pack. After the cement sets, the molds of the endotracheal tubes were removed. The diameter of the stems was re checked at this stage to confirm that they were not oversized by passing them through an intramedullary nail gauge.

The femoral stem was placed in the canal with the female hinge remaining just outside the canal. A double loop of 1.5 mm tension band wire was passed through the hole in the female hinge and placed over the condyles to have a better cement-steel construct of the distal and posterior augments. A fresh 40 gm cement pack was opened and prepared with similar antibiotic addition. The composite tibiali component (PS poly with Ilizarov rod and antibiotic cement construct) was cemented in place with a "poor" cementing technique. The femoral component in an appropriate position and rotation was placed over the stainless steel wire and the hinge with the same "poor" cementing techniques. The poor cementing technique would include: leaving blood to prevent good inter-digitation between bone and cement and pulling out the component a little before final seating to ensure a lack of complete locking. The knee was reduced and put through a range of motion arc and then held until the cement set.

After thorough lavage and hemostasis, the wound was then closed in layers without a drain.

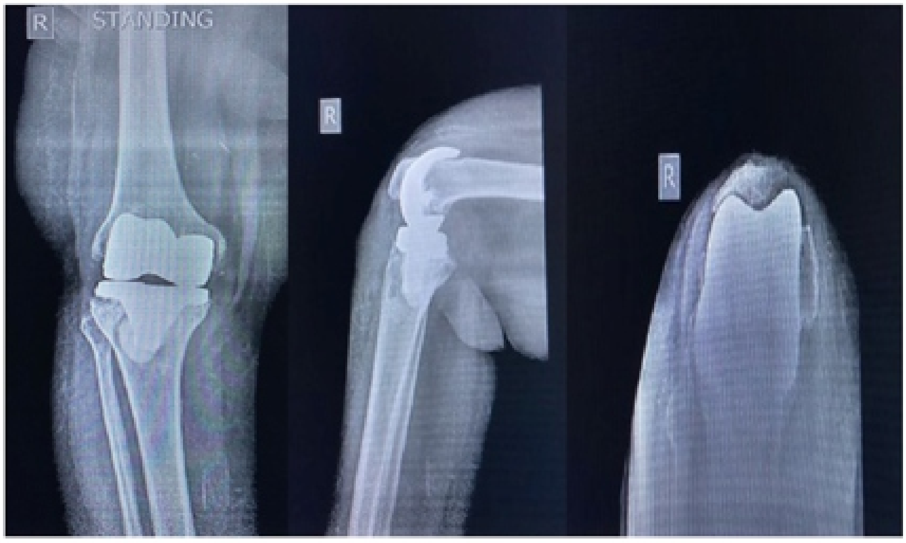

Fig. 3. Pre-operative radiographs

Post-operative radiographs (Fig.4) were ordered and weight bearing was started as tolerated. Broad-spectrum IV antibiotics were started immediately till the confirmed culture and sensitivity reports were available and oral antibiotics were given for 3 weeks. Suture removal was done at 15 days. The patients were followed up every 15 days until the second stage. ESR, CRP was done weekly for first two weeks and then, every two weeks until the oral antibiotic therapy. If the ESR, CRP were within normal limits along with clinical and radiological signs of infection control, definitive surgery was planned.

Fig. 4. Post-operative radiographs.

3. Discussion

Prosthetic joint infection (PJI) forms one of the common indications for revision (20.4%) total knee replacement.1

The incidence of Prosthetic Joint Infection in India has been found to be around 1.1% in a single institute by Sebastian S et al.5 Majority of them are caused by multidrug-resistant Gram-negative bacteria (64%), Aerobic Gram-negative bacteria (61%) and Methicillin-resistant coagulate negative staphylococcus (45%). Thus, in India, there is a higher need for a two-stage revision TKR for Prosthetic joint infection.

Patients with articulating spacers had better ROM, knee score, and less bone loss than patients with static spacers. But, Fink B et al. have shown that these all-cement spacers do abrade within 6 weeks. They suggested radical debridement and total synovectomy with extensive lavage during the second-stage replantation to minimize the number of abraded particles.6

Prefabricated molds have shown better results in terms of ROM compared to static spacers but becomes a costlier technique for the pa tient.1,3 With all-cement spacers, the quantum of cement and antibiotics is fairly high. Acute kidney injury after antibiotic cement spacers has been documented in a fairly high number of patients.7

In 1995, Hoffman AA et al. first described the use of real components by autoclaving the removed components with antibiotic cement in 26 patients. They showed good results. Since then, many authors have done a similar method and have shown similar results.1,2

Results of two-stage revision between the autoclaved metal-on cement spacer and static spacer in periprosthetic knee infection have shown similar results in eradicating the infection with both techniques, but ROM after re-implantation was much better with autoclaved components than static spacers.7

We have used new components along with Ilizarov components as a spacer. On the femoral side, along with the real femoral component a threaded rod with a female hinge of Ilizarov in inserted in the medullary rod with nuts at the end aids in the removal of the construct. Using an Ilizarov threaded rod makes the process of spacer removal simple and quick, without leaving any residue inside the canal.

The stainless steel wire is passed through the female hinge and fixed underneath the cement component. This allows for ensuring a good cement-steel construct over which the component rests. It is also very useful while removal of the spacer as the wires binds the intramedullary stem together with the component.

On the tibial side, a similar threaded rod is put which is fixed with a tibial polyethylene component. In Indian conditions, where the implants are under price control, the cost of an all-polyethylene component is more than twice as much as a regular polyethylene. Thus, using a thicker regular polyethylene and making keel out of bone cement makes it very cost-effective and stable. Also, using cement in the entire keel area would ensure good clearance of infection for use of subsequent metaphysical cones and wedges. Using the threaded rods with nuts for stem would aid in strength and ease of removal. Also, even if, the tibial component poly breaks during removal, the extraction of the threaded rod stem is simple. One can attach a female hinge on top of the threaded rod and back slapped with a regular extractor using the female hinge as the eye of the nail.

Lyons S et al., in 2019 have published their results of using real component knee spacers in 55 patients. Out of these 40% of their patients chose spacer retention at an average of 3.3 years. They concluded that articulating spacers with real components provides excellent infection control and good functional outcome. And the same implant can be retained for an extended period of time similar to a single-stage pro cedure.3 In 2020, Gililland JM et al. showed their technique of making the articulating spacer with real components. They have used two Steinman pins into the tibial all poly component.9 But, smooth constructs like wires, nails can have complications like cement de-bonding. Cho et al. have shown that using a threaded Ilizarov rod makes the process of spacer removal simple and quick, without leaving any residue inside the canal.10

Spivey JC et al. have done a systemic meta-analysis of 34 articles. They found that metal on polyethylene articulating spacers had a significant increase in joint ROM compared to other types of spacers without difference in infection eradication.8 More recently, Roof MA et al., in 2021 have shown that real components have significantly shorter hospital stays which reduces patient morbidity and mortality. Also, it reduces hospital cost. They concluded that real components shorten operating time, blood loss, and improve patient recovery and ease of re-implantation. Thus, making them superior to all-cement spacers.4

In our study, there was improved range of motion in all patients with an average of 100 degrees. At the time of last follow up all patients were symptoms free with control of infection.

Definitive fixation in 2nd stage was uneventful in all patients.

4. Conclusion

Using real components of TKR, with Ilizarov's components and stainless steel wire makes a simple mobile spacer, which has benefits of improved function and good infection control during the intermediate phase and ease of surgery in the second stage.

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ALIGNMENTS IN TKA

THE ICARUS SYNDROME OR THE PERSEUS CHALLENGE?

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INTRODUCTION:

In recent times, the concept of alignment in total knee arthroplasty (TKA) has become an increasingly complex subject. In fact, the complexity has reached proportions which is daunting for most surgeons to fully understand. I would not be surprised if a young surgeon finds it a petrifying experience faced with the challenge of integrating the different alignment methodologies in his practice.

It is indeed the Greek legendary story of Medusa's head and its effect on any soldier who came to confront her, and the challenge which Perseus faced when asked to behead her! (Figure 1).

Fig. 1

Fig. 2

For those few who are able to behead Medusa (meaning – understand these complex methodologies), I caution them not to suffer at the altar of the Icarus syndrome! (Figure 2)

I request the readers to read up what these Greek mythological stories have to offer in the present context.

This essay aims to describe the different types of coronal alignments in Total Knee Arthroplasty (TKA), and correctly defining the main principles and terms associated with specific alignment methods. However, to grasp these concepts we must first understand the context in which these alignments have evolved.

Why has this become a matter of intense interest despite the fact that the conventional method of mechanical alignment (MA) has yielded an extremely high rate of success in terms of improvement in functional results and long-term survival of the implant construct?

It all boils down to the observation that around 10 to 20% of patients undergoing TKA continue to have some niggling discomfort in their knees which prevent them from "forgetting" that their knee had undergone a surgical procedure. This is unlike what patients who have undergone total hip replacements experience. It is the aim for achieving a situation of hundred percent "forgotten knees" that has given impetus to the idea that perhaps something can be done which would improve on the present status.

Whilst the above discussions were going on within the arthroplasty fraternity, Bellemens (2011) published his seminal paper:

"Is neutral mechanical alignment normal for all patients?

The concept of constitutional varus".

In this paper he emphatically brought home the point that patients who were completely normal and had no symptoms related to their knees demonstrated a hip, knee and ankle (HKA) axis which was demonstrating an overall constitutional disposition of varus in their lower limbs. He questioned the existing philosophy of putting all knees undergoing TKA into a neutral mechanical alignment, suggesting that perhaps some patients have residual symptoms because their soft tissue envelope around the knee was designed by nature to accommodate a varus constitutional orientation of their lower limb (Figure 3).

Fig. 3

It is to be noted that in this study he had not recognized the independent relationship of jointline obliquity (JLO) with the overall constitutional hip, knee and ankle phenotype. This point was brought home in a paper which followed 10 years later in which MacDessi and Bellemens clearly demonstrated that all human beings can be classified into nine patterns of physiological phenotypes. This paper is titled:

"Coronal Plane Alignment of the Knee (CPAK) classification" (Figure 4).

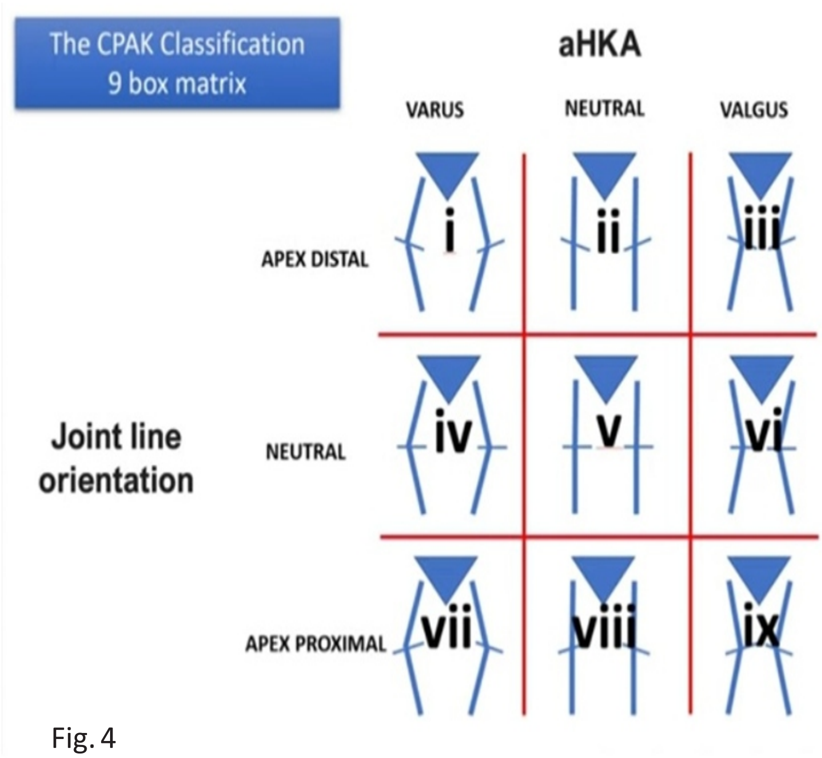

Fig. 4

The recogni on of these anatomical varia ons immediately triggered the discussion that the alignment and component posi oning, that is aimed for during TKA, should perhaps be targeted as per pa ent's own physiological phenotype rather than a standardized approach of neutral mechanical alignment.

ALIGNMENTS:

Thus, the following different alignment philosophies have emerged (Figure 5)

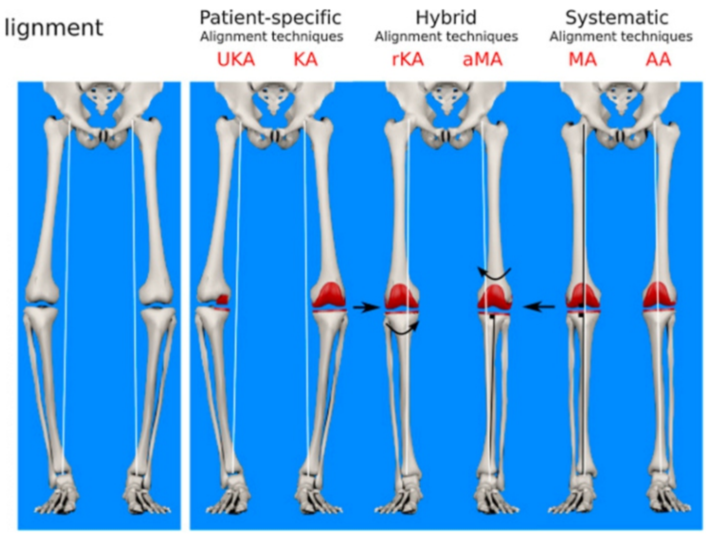

Fig. 5

SYSTEMATIC ALIGNMENT:

1. Mechanical alignment (MA).
2. Anatomic alignment (AA).

PATIENT SPECIFIC ALIGNMENT

3. Kinematic alignment (KA).

HYBRID ALIGNMENT

4. Restricted kinematic alignment (rKA).
5. Inverse kinematic alignment (iKA).
6. Adjusted mechanical alignment (aMA).
7. Functional alignment (FA).

Let us look at the salient features of each of the above alignment methodologies.

1. MECHANICAL ALIGNMENT (MA):

This was the approach proposed by Ranawat and Insall (1970).

Principle:

Position both femoral and tibial components perpendicular to the mechanical axis to obtain a HKA angle of 180° after ligament release. This would give a symmetric balanced load on the implants, which minimizes wear and component loosening.

Clinical Results:

This is still considered to be the gold standard. There is ample evidence to demonstrate that with this method the implant survival can be as high as 95% at 20 years. Clinical results are reported to be excellent by different scoring methodologies.

Criticisms:

In the patients treated with this alignment method, there have been a residual group who report some dissatisfaction with the experience and this has come to be known widely as the 20% deficit in the "forgotten knee" test result. It is theorized that the reason for this could be that in this methodology, all patients are subjected to a neutral HKA angle orientation post operatively, leading to abnormal JLO and alteration of normal knee biomechanics for those patients who had a physiological constitutional varus (or even valgus) orientation with a JLO which could have been apex down or up (refer the CPAK classification).

2. ANATOMICAL ALIGNMENT(AA):

This approach was proposed by Hungerford and Krackow (1980).

Principle:

Position the femoral component in a fixed position of 3° valgus and the tibial component in a fixed position of 3° varus relative to the mechanical axis of the limb giving a JLO of 3° apex down, while restoring the HKA angle orientation to 180° in all patients.

Clinical Results:

Lack of long-term data on implant survival.

Criticisms:

Main concern is an inadvertent over resection of more than 3° in the proximal tibial cut leading to implant and fixation failure.

This type of alignment was abandoned because technology at that point in time was not available to offer a predictable safeguard against executing a tibial cut of more than 3° varus.

3. KINEMATIC ALIGNMENT (KA):

This approach was proposed by Howell (2008).

Principle:

To restore the pre-arthritic HKA angle and the pre-arthritic JLO, and thus the natural tension of the ligaments in that knee. This method aims to be a "true femoral resurfacing" procedure wherein cartilage and bone thickness removed would exactly match the femoral implant thickness in the distal and posterior segments. The tibial resection is done parallel to the femoral resection without any soft tissue release. For this reason, it is called a patient specific technique involving only bony resection.

Clinical Results:

Studies reporting the results are very heterogeneous. Comparing the results with MA do not show any statistically significant improvement in clinical, functional and long-term survival results.

Criticisms:

There is a risk of putting the tibial component into dangerous degrees of varus/valgus inclination. The critics point out that it is difficult, if not impossible, to judge the pre-arthritic status in bilaterally affected knees with advanced cartilage and bone erosions. In absence of data about what the normal status of the knee was, prior to the arthritic pathology setting in, it would in any case become speculativein terms of what the surgeon is trying to achieve - whichis, a completely synchronous alignment of the lower limb bones and the artificial components via-a-vis the soft tissue envelope of the knee capsule, as it existed prior to the arthritic status.

4. RESTRICTED KINEMATIC ALIGNMENT (rKA):

This approach was proposed by Venditolli (2011)

Principle:

rKA follows the main surgical technique of KA; but it restricts the HKA angle within +/- 3 degrees and JLO within +/- 5 degrees, even if the patient's anatomy would indicate corrections of higher values.

Clinical Results:

Studies with long term clinical results are absent.

Criticisms:

The authors themselves admit that 50% of patients would have less than natural anatomical correction for their post arthritic deformities. This defeats the lofty ideal of giving a perfectly 'natural' post operative status.

5. INVERSE KINEMATIC ALIGNMENT (iKA)

This approach was proposed by Winnock de Grave (2022).

Principle:

This claims to be a “true tibial resurfacing” with equal medial and lateral resections on the tibial plateau maintaining the native tibial JLO. The flexion and extension gaps are balanced by measuring the femoral resections with none or minimal soft tissue releases. It results in a less post operative varus of tibial joint line.

Clinical Studies:

Authors reported no significant difference in clinical results between iKA and aMA (adjusted mechanical alignment) at 12 months.

Criticisms :

No studies with mid or long-term data available

6. ADJUSTED MECHANICAL ALIGNMENT (aMA):

This methodology was proposed by Zheng (2021).

Principle:

It is an adaptation of the classical MA approach. Implant position adjustments are made on femoral side. The tibial component is placed perpendicular to MA.Six degrees of residual varus/valgus is accepted and addressed by minimal ligament release for extension gap balance, and external rotation of femur for flexion gap balance.

Clinical Results:

No studies with mid or long-term data available.

Criticisms:

No study demonstrates superiority of aMA in terms of clinical outcomes or survival of implants when compared to the classical MA methodology. The technique does require soft tissue release.

7. FUNCTIONAL ALIGNMENT (FA)

This methodology was proposed by Kayani (2020).

Principle:

Aim of this technique is to restore the natural JLO and balance flexion and extension gaps by adjustments of tibial and femoral components avoiding soft tissue releases. The use of robotic technology is a prerequisite. Adjustments are done in coronal, sagittal and axial planes. Soft tissue releases are considered in severe fixed deformities.

Clinical results:

Kayani, the main promoter of this alignment method, reported comparable WOMAC scores in MA versus FA groups 2 years after surgery.

Criticisms:

No studies with mid or long-term data available. The mandatory use of robotic technology increases the cost.

COMMENTARY:

The subtitle of this present essay indicates the author's take on the subject of alignment in TKA.

I will expand on this bit in my concluding statement. At this stage, I would like to point out that part of the momentum which has been built up in the discourse, on which of the above alignments might deliver the Holy Grail, is due to the introduction of technologies such as computer aided navigation and the additional layer of robotic assisted TKA. These in turn have the pushing capacity of any new technological development which brings with it a set of enthusiasts, and then it also has the push of commercial interests.

A significant amount of justification offered for the use of these cost additive technologies is on the grounds that to achieve this very tiny modulation of component positioning (JLO) and HKA angle targets,

the use of above-mentioned technologies would be inevitable.

I would like to bring to the attention of the reader the difference between the terms: “Accuracy” and “Precision”. These are often taken as being the same.

ACCURACY is when you hit the actual target.

PRECISION is when you hit the target for which you aimed (Figure 6).

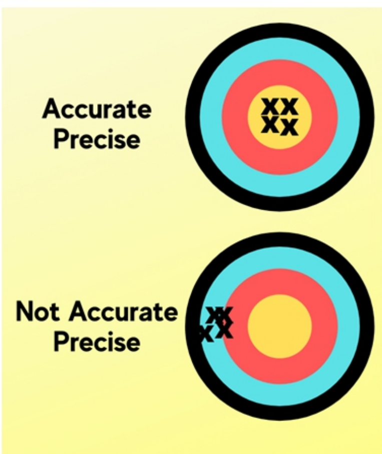

Fig. 6

To be perfect, you would need to know what is the actual target, then aim for it, and hit it every time.

This by implication means that you should know what the actual target is every time you take aim. If you have no means of knowing what your actual target is, you might be precise and yet not be perfect in your shooting.

In other words, you would be hitting the target you chose every time with precision, but this would still be inaccurate because it was not what the actual target was supposed to be.

The entire concept of KA is handicapped by the fact that osteoarthritis of the knees is usually a bilateral pathological process and by the time a patient presents to the clinician for arthroplasty surgery the pathological processes would have affected both knees and lower limbs to a significant extent.

How do you know in a given patient what was the normal JLO, and what was the initial constitutional

limb alignment (HKA angle), when both knees are significantly altered by the disease pathology?

How do you accurately decide on the thickness of the lost articular cartilage and bone due to advanced disease pathology?

How do you accurately decide on the bony thickness (kerf) lost due to the sawing?

Let us remember that the entire effort, and justification, of KA and the associated methodologies, revolves around 2 to 3 degrees of coronal plane JLO modifications and similar in the rotational aspect of the femur and tibial component placement.

In fact, every KA pioneer has admitted the risk of overshooting these targets, and entering the unsafe zone of JLO,thus risking early failure by loosening and/or tibial plastic breakage. Therefore, almost all proponents of these “physiological” alignment methodologies have recommended this approach to be reserved for only “mild” deformities. There is no established definition of what is to be considered as a “mild” deformity.

At the heart of the philosophy of KA and associated alignment methodologies is the belief that by measuring, and executing tiny changes in the bone cuts during TKA, one would be perceptibly impacting the final clinical, radiological and survival results of TKA to achieve the Holy Grail of 100 % “Forgotten Knees”!

There is one additional thought line which I would like to mention here as part of this essay, although it has no immediate relevance to the subject of alignment philosophy.

The entire premise of trying to use these different alignment methodologies is based on the aim to achieve a situation wherein the capsular soft tissue envelope around the knee finds itself completely accommodated by the hard anatomy as if it is in the same state of tension as it was when the knee was pre-arthritic.

This is supposed to happen even during the entire dynamic range of movement of the knee when in full function, in an active patient, after the TKA surgery.

If one ponders on the nature of how anatomy evolves in any part of the body, it becomes obvious that the various ligaments which form the capsular envelope around the knee are made up of fine fibres oriented between the two bony parts of the hard anatomy, in a manner which brings them under tension at various points in the arc of movement from full extension to full flexion. This tensioning of individual fibres of the ligaments (e.g. collaterals) is intricately connected to the contours of the lower end of femur and upper end of tibia.

Once these change, the ability of the individual fibres to come under the appropriate tension, at the appropriate stage of the flexion arc, will also change from the normal.

In other words, unless we are able to re-create the volume and contour of the lower end of the femur and the upper end of the tibia to the pre-arthritic anatomy, it is a theoretical impossibility to have a soft tissue envelope which will function as per what it was designed to do so in normal kinematics of that given knee. The only way to address this theoretical possibility would be to come up with a system with implant components which match the volume and contours of the patient's pre-arthritic hard anatomy.

AUTHOR'S PREFERRED METHODOLOGY:

By now, the reader would have surmised that the present author is not convinced about the gains versus the pains, in terms of the additional cost and complexity of integrating elaborate technology, in what is otherwise a proven and predictable surgical exercise.

The MA methodology is supported by extremely strong principles of structural engineering for the long-term survival of the implant construct. It has already shown an extremely high rate of efficiency in delivering significant clinical improvements on all counts. Given the above fact, I do not find the justification in adopting a methodology which will add to the cost and complexity of the procedure, while not providing any evidence to show that MCID are achieved via-a-vis functional and survival results.

SUMMARY:

There is a cultural pattern that has become ubiquitous in recent decades, engulfing an ever-widening range of institutions, healthcare delivery being no exception!

For convenience, let's call it metric fixation. (Metric – a system for measuring something).

A key premise of metric fixation concerns the relationship between measurement and improvement.

Metric fixation is the seemingly irresistible pressure to measure performance, to publish it, and to reward it, often in the face of evidence that this just doesn't work very well.

The problem is not measurement, but excessive measurement and inappropriate measurement - not metrics, but metric fixation!

The most characteristic feature of metric fixation is the aspiration to replace judgement based on experience with standardised measurement. For “judgement” is understood as personal, subjective, and self-interested. “Metrics”, by contrast, are supposed to provide information that is hard and objective.

Metric fixation leads to a diversion of resources away from frontline practitioners in need of resources for solving relevant and immediate problems to (sometimes) non-existent, or much less relevant problems. Because belief in its efficacy seems to outlast evidence that it frequently doesn't work, or add any value, metric fixation has elements of a cult.

Studies that demonstrate its lack of effectiveness are either ignored or met with assertion that what is needed is more data and better measurement!

This is certainly the case in the field of TKA. Review after review, including umbrella reviews, show that there is no high-quality evidence to support the hypothesis that introducing tiny changes of HKA and JLO iterations which KA and associated methodologies advocate, bring any Minimal Clinically Important Difference (MICD). This is evidenced when one reviews the literature on mid- and long-term results of the use of Computer Aided Navigation TKA, and more recently, Robotic Assisted TKA.

Metric fixation, which aspires to imitate science, too often resembles fait

All of that is not intended to claim that measurement is useless. To be sure, there are many situations where decision-making based on standardised and precise measurement is superior to judgement based upon personal experience and expertise.

If what is actually measured is a reasonable proxy for what is intended to be measured, and if it is combined with judgement, then measurement can help practitioners to improve upon their own performance, both for themselves and those whom they serve.

Ultimately, the issue is not one of metrics versus judgement, but matrix as informing judgement - which means knowing how much weight to give to metrics, recognising their potential to offer distortions, and appreciating what can't be measured.

The Metrically Fixated failed to realise that:

Not everything that is important is measurable,

and much that is measurable is unimportant.

Remember … that sometimes recognising the limits of the possible…

is the beginning of wisdom!

KINEMATIC: UNRESTRICTED, RESTRICTED, INVERSE KINEMATIC ALIGNMENTS

Dr.Jyotish G.Patel,

Dr.Vaibhav N.Vyas

INTRODUCTION

Despite the many advancements and improvements indesigns as well as assistive devices to improve the accuracy and precision in total knee arthroplasty, the functional outcomes can remain disappointing. Hence, alternating ways of alignment methods havegainedinterest.

Kinematic alignment is a technique for total knee replacement which aims to reconstruct patient specific limb alignment and knee biomechanics based on the pre-arthritic kinematic axis of the patients' femur. It is considered as a ligament sparing technique as it relies on bone cuts to recreate pre-arthritic kneelaxities and compartment forces.

HISTORY

Although many designs predate the total condylar prosthesis designed by Insall and others, its introduction in 1973 marked the beginning of total knee arthroplasty era.(1)Total Condylar Prosthesis (TCP) was the first model of total knee replacement:it was designed in the '70 with a Chrome- Cobalt femoral shield and two components in polyethylene (Tibial and patellar)

Insall-Burstein Total Condylar Knee had a more posterior point of contact. With the perfection of the cam-and-post mechanism other designs of TKA reached1 10°degrees of flexion. However, anatomic approach provides a prosthetic design that could fit ligament anatomy and functionality, without sacrifice.

Leeds,Knee,Buechel and Pappas were other supporters of the “anatomic” choice. They contributed in the realization of a mobile meniscal bearing resurface prosthesis. (4) The menisci independently slip on curved tracks, favoring the axial rotation of the femur. These achievements were fundamental for the development of the modern LCS(Low Contact Stress)prosthesis.

In other successive model like Rolamite's one the axis of rotation moves moving back in the course of flexion(5)

Evolution of rotating platform knee Wear and loosening problems associated with knee joint replacements have been one of the major mechanical causes of failure since their early use int he1970s.(6–12)The development of mobile-bearings reduced the risk associated with these problems by allowing needed mobility to minimize loosening torques on fixation while providing an increased surface contact area on the bearings to reduce wear.(13–22)

Various types of mobile-bearing low-contact-stress(LCS) total knee replacements were developed to fulfill the requirements posed by existing pathologies and deformities. The bicruciate-retaining meniscal bearing total knee replacement was replaced by the posterior cruciate-retaining meniscal-bearing knee,mainly because of bial component loosening problems and surgical difficulty in retaining an intact anterior cruciate ligament(14,23) ,even though good results were reported.(24)
The rota ng-pla orm type mobile-bearing was developed by F.F.Buechel., Sr.and M.J.Pappas and ini ally used in 1978as a revision prosthesis to salvage failed bicompartmental fixed- bearing knee replacements.(25)
subluxation or rotatory dislocation, sometimes referred as "spin-out"of rota ng pla orm bearings have been observed in 1-2 %of cases by various authors.(26,27) The cause for this “spin-out”appears to be flexion instability at the me of surgery.(13,28,29)

Design modifications

The third generationBuechel-Pappas knee retains commonalities with specific variants of the LCS.Also, some key design features were added to the Buechel-Pappas knee replacement system. The B-P knee design uses a generating curve around a series of parallel axes (Fig. 1) producing two spherical regions in the principal load bearing segment, which provides for more flexion. The dimensions of the articulating surfaces of the B-P knee are such that fully congruent contact exists to about full flexion. Full line contact occurs with the B-P knee at greater flexion angles while the LCS has quasi-line contact at these flexion angles. The primary load bearing segment arc of the B-P femoral component is greater , thereby increasing the degree of congruent contactduringflexion.A comparison of testing demonstrates that stresses in the B-P are substantially lower than the LCS knee at all flexion angles.(30)

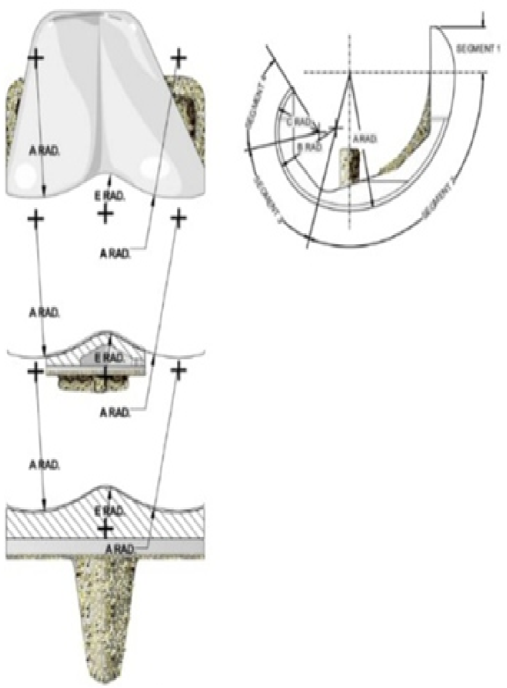

Figure 1

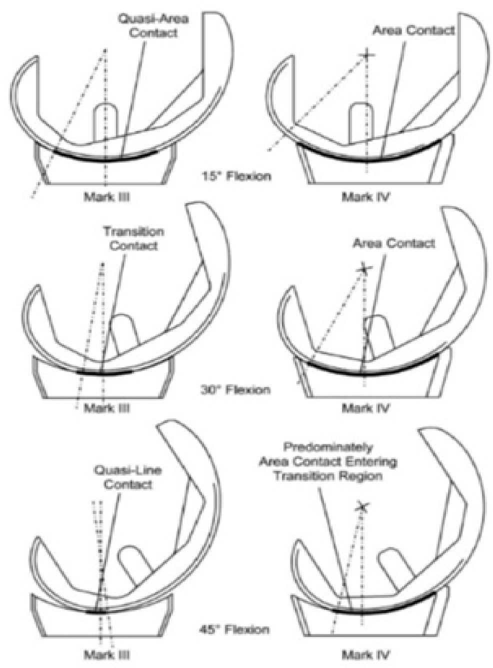

Figure2

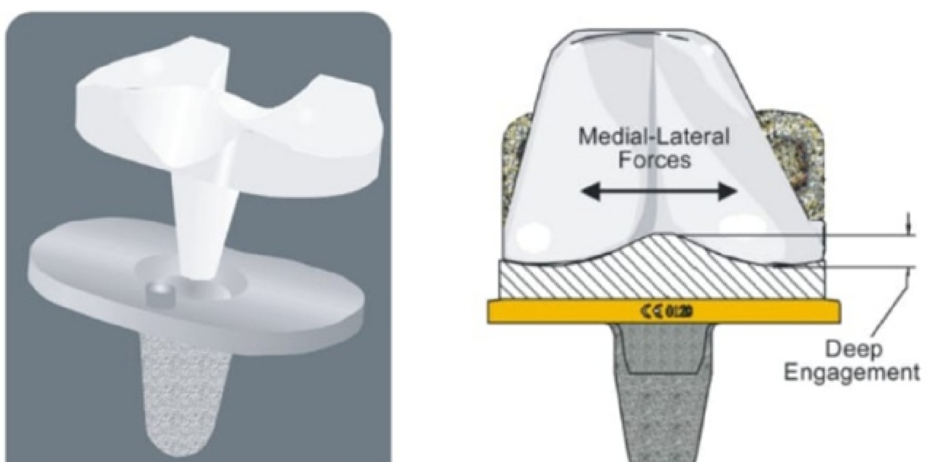

Figure3&4

The B-P tibial platformis anatomically shaped and contains a stop pin to limit bearing rotation and reduce the potential for spin-out. The stop pin on the superior surface of the tibial platform engages a slot in the inferior surface off of the bearing and provides axial rotation. The limits of the rotation are not encountered during any activity but are reached onlyin the event of subluxation of the bearing from the femoral component. This stoppin reduces the potential for spin-out as seen in the LCS.In LCS, the combined effects of an A-P shearing load, distraction of one of the condylar compartments and a lax collateral ligament associated with the distracted compartment,demonstrate that the rotating bearing can be forced to rotate to a dislocated position.With the LCS,only ligament tension sufficient to prevent the femoral condyle on the distracted side from climbing over the lip of the bearing can prevent such dislocation.(fig3)(30)

Since the bony structures naturally providing this stability are resected, the generating curve in Buechel-Pappas is designed to provide congruent medial-lateral stability.

Mechanical Alignment

Described by Insallet al., the mechanical alignment is the widest method used inTKAprobably for the high reproducibility and easiness.

Total knee arthroplasty has aimed to achieve neutral alignment of the lower limb, with hip-knee-ankle (HKA)angle of00.In mechanical alignment, both femur and tibial components are being perpendicular to the mechanical axes and parallel and equal gaps in flexion and extension.

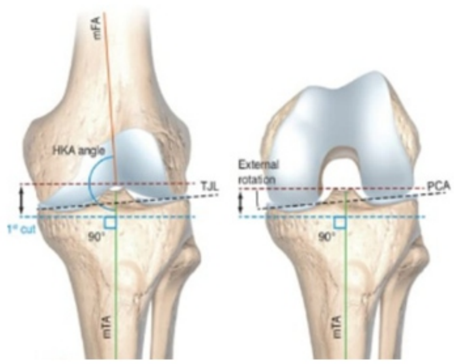

Figure5

Strive to mechanically align any knee may pose some problems related to ligament misbalancing that could explain the high rate of disappointed patients, almost 20%in some reports.

Aiming to mechanical alignment only, may arise undesirable kinematic consequences- if femoral and tibial components are positioned in such a way that the new joint line is raised and not parallel or perpendicular to the three axes that describe tibio-femoral and patella-femoral kinematics.

A so called kinematic alignment has recently been developed in order to improve patient's knee function and pain control minimizing any surgical gesture focused on ligaments balance.
The amount of bone resections may not affect limb alignment but has an important consequence in ligament tension and balance, clinical result and function therefore a measured bone resection technique is essential in order to perform a proper kinematic alignment.
The idea of kinematic alignment is not totally new: it is inspired indeed from the concept of anatomical alignment of Hungerford and Krackow.

Kinematic Alignment:overview

A KA-TKA procedur eaims to restore the native joint kinematics of the patient, which were present before the onset of arthritis. This procedure preserves the patient's tibiofemoral joint line, leaving the LDFA,MPTA, and HKA unchanged. Since these angles remain unchanged, ligament releases are often not needed and both the medial and lateral ompartment forces of the native knee are restored

During a KA-TKA procedure,ensuring that the resected bone and cartilage's thickness is equal to the implant's thickness at the distal and posterior cuts of the femoral condyles and each tibial plateau is crucial. In cases where preoperative varus or valgus deformity exists, the patient should be left with the same degree of deformity postoperatively to maintain the patient's individual tibiofemoral joint line.Thus, the aim of KA-TKA is to attain an HKA axis that matches the patient's preoperative alignment .

Why KA-TKA?

The concept and technique of KA for TKA has been developed following the observations that mechanically aligned TKAs are affected by residual complications that haven't been solved by technology, thus suggesting intrinsic technical limitations.

The proportion of residual knee symptoms(e.g. pain, effusion, instability) and patient dissatisfaction after MK-TKA has been reported to be as high as 50% and 20% respectively.(31-35) It is interesting to know that neither the modern TKA designs nor the many technological assistive devices have solved the issue.

Aiming at a similar component implantation alignment goal, the MA-TKA does not recreate high variability in knee anatomy and laxity between individuals. This may be responsible for non-physiological knee aligament laxities and instability and abnormal kinematics.

Kinematic Alignment

The development of a kinematic alignment aims to realize awell-balanced artificial joint during the whole arc of motion. The concept of kinematic alignment has gained interest since the description of the different transverse axis of the femur and of the cylindrical shape of the posterior part of the knee condyles.

As implant technology has improved, the issue of component wear and loosening has dissipated, and the concept of restoring a patient's native anatomy has gained increasing traction in the orthopaedic community. KA is true 'resurfacing' of the knee joint in which the aim is for the implant thickness to replace the exact amount of 'bone/cartilage' removed and therefore restore the highly variablepre-arthritic knee joint orientation. KA is thought to improve function whilst also reducing the incidence of pain associated with TKR. KA aims to restore thepre-arthritic alignment of the knee by positioning the femoral and tibial components to restore native joint lines, theoretically without limit the amount of post-operative correction.

What are the potential benefits of KA?

By being more physiological and restoring the three kinematic axes of the knee, it is thought KA-TKA provides a superior outcome to MA. The three axes are:

1. The transverse axis (trans-epicondylar or cylindrical axis)inthefemur,about which the tibia flexes and extends

2. The transverse axis in the femur,about which the patella flexes and extends and

3. The longitudinal axis in the tibia,about which the tibia internally and externally rotates on the femur.

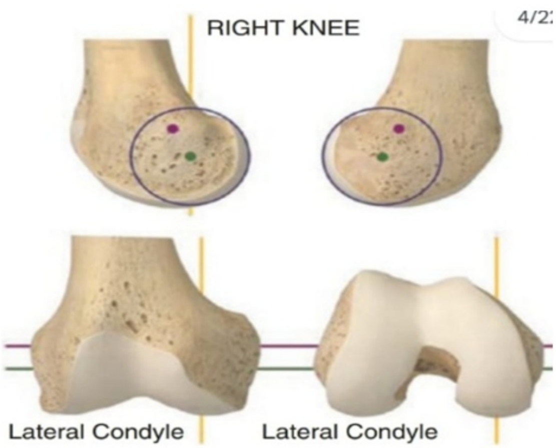

Figure6

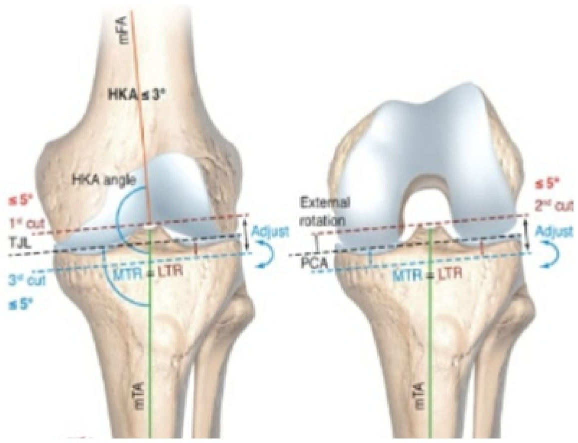

Figure 7

The key principal of the KA approach is that restoration of these three axes, the joint line orientation angle (JLOA) and physiological soft tissue balancing will improve gait,feelof the knee and range of motion(ROM);and thus, result in superior patient outcomes.

The KA technique aims to improve prosthetic knee function,patient satisfaction and component lifespan, as compared to conventional techniques. The anatomic knee reconstruction has been shown to be clinically beneficial by means of the near physiological peri-prosthetic soft-tissue tension. The kinetic aspect of a KA-TKA may also be advantageous in terms of reduced joint reaction force, compared to MA-TKA.

METHODS

In a study, the method used to produce kinematic alignment was “shape match”, which involved a proprietary method of obtaining a magnetic resonance image of the knee, using a computer algorithm to fill in the worn areas of articular surface, place an image of the knee prosthesis and then create a three dimentional-printed cutting guide used in surgery to there sections for the femur and tibia.(36,37)

Proponents of KA argue that anatomic component position will improve clinical results compared to MA technique by reducing the need for ligament releases and improve soft tissue balancing.

However, it is known that increasing the physiological tibial varus or slope might lead to an overload of the bone interface or early implant loosening.

RESTRICTED KINEMATIC ALIGNMENT(rKA)

The r-KA follows the principles of kinematic alignment by adjusting the cuts in case of outliers.(38)

The r-KA aims to restore native knee kinematics, avoiding extreme deformities. Clinical outcomes not inferior or even better for rKA compared with MA, without increasing the risk forshort-middle-term implant failure.However,further studies with a large sample size are needed to confirm the statistical superiority of r-KA compared with MA.

INVERSE KINEMATIC ALIGNMENT

The limitation of correcting ligament balancing with a tibial recut is that the resurfacing of the femur is at the expense of adjustment with the tibial cut. If the tibial recut is necessary, it poses two difficulties:

1. A more oblique and deeper cut will result in loss of medial tibial bone stock. Increasing the tibial resection could jeopardize the MCL

2. An increased tibial recut impacts the flexion and extension gaps. In complex cases where the recut may be asymmetrical, it could lead to laxity.The principle of inverse kinematic alignment is to resurface the tibia with similar medial and lateral resections after correcting for wear, maintaining thepre-articular tibial joint line obliquity. Then the gap balancing is done by adjusting the posterior and distal femoral cuts. This technique could avoid too much resection of tibia and related complications. The advantage of this technique is that the flexion and extension gaps can be managed independently.

However, it is a challenge to perform inverse kinematic alignment accurately with conventional instrumentation or patient specific guides. A robotic assisted system enables intraoperative planning of bone resections and gap balancing before the cuts.

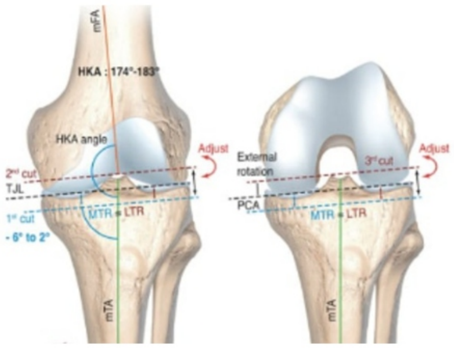

Figure8

Followup

Patients undergoing TKA with KA experienced less pain 6weeks after surgery and higher Forgotten Joint Scores at 1 and 2 years postoperatively. Alternative TKA alignment and balancing strategies should be considered to increase patient satisfaction.

In a study observing the2 year results of the first prospective RCT comparing KA vs MA TKA,theKA-TKA demonstrated superior 2year patient reported outcomes.(39)

Howell et al has previously published mean 10year follow-up for KA-TKA and noted survivorship was 97.5%for revision for any reason and 98.4%for aseptic failure.(40)

Thus, the KA-TKA technique, which attempts to maintain the natural kinematic axis and ligament balance of the individual knee, has increased in popularity.

Conclusion:

Total knee replacement surgery for osteoarthri s of knee is an established and result oriented procedure. With newer technological advances and understanding of biomechanics and anatomical alignment for be er outcome of surgery has led to change in surgical technique from mechanical alignment and measured resec on to kinema c alignment and so ssue gap balancing. Enough data with 10 years survivorship and clinical outcome has proved be er sa sfac on and func onal aspect for pa ents undergone TKR by kinema c alignment and so ssue gap balancing technique.

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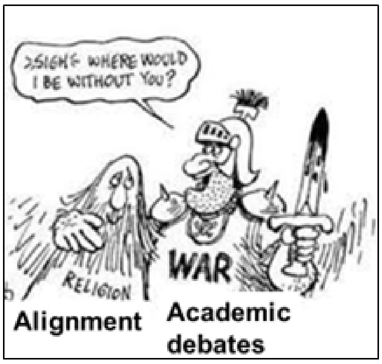
“BALANCE” AMONGST ALIGNMENTS

Dr. Manish Shah, Dr. Ketan Shah, Dr. Pareen Kantesaria

With increasing digitization and an increasing ability to achieve a desired target, various alignments along with their subsets have been born. All the different alignments, including their subsets, claim excellent results. Emerging registry data also shows that all of them have good results.Abdel MP and Parratte's work on the twenty-year follow-up of the cohort of patients with varying alignments proves that within a reasonable limit, all alignments give good results throughout the twenty-year span1! If all alignments and their subsets work with similar success and failure rates, trying to tweak them furtherwill not lead to any further improvements in results! Probably, in the search of the “Holy Grail” of knee replacements, the cup of alignment is not the “Holy Grail” !



In GOA bulletin, they are discussing which alignment is best......

Let us step back a little. Insall stated that total knee replacement surgery is “a soft tissue surgery”. The aim is a well-aligned ANDwell-balancedknee.But we also know that soft tissue releases can be unpredictable. A 1 mm soft tissue release will not necessarily open the flexion or the extension space by 1 mm. Also, the gradient of the release is equally unpredictable. The first couple of millimeters of release might not open the flexion or the extension space much but a small increment can suddenly open the space massively. Besides, soft tissues releases have been associated with early post-operative pain. As the battle to improve results intensifies, surgeons are looking for options where the soft tissue releases are minimal, and the correction remains predictable.

The work of Simon Young and others based on the data from robotic knees published in 2023 is an “eye-opener”2. There are more than 8000 combinations of alignment and component placements which give a balanced knee. Thus, even with robotic knee replacements, no two robotic replacements may be alike. They would vary from surgeon to surgeon regarding the component position and balance based on the surgeon's preferences. Simon Young and others found that pure Mechanical Alignment gives equal gaps in only 1% of more than 300 patients while pure Kinematic Alignment gives equal gaps in 0% patients. If deviation of +/- 3 degrees is accepted, equal gaps were achieved in 54% with mechanical alignment and 51% with kinematic alignment. If lateral gap laxity (up to 1 mm in extension and up to 3 mm in flexion) is accepted along with +/- 3 degrees from median, balance was achieved in 79% with mechanical alignment and 88% with kinematic alignment.

Thus, has been born the concept of “Personalized Alignment”. It is defined as “placing the componentsin a position that least compromises the soft tissue envelope of the knee.”The first step is understanding the patient's anatomy. Knowing the distal femur valgus, proximal tibia varus and the joint opening and subluxation. The first two variables define the CPAK classification.

The work of MacDessi and othersin 2020 has shown that the subtypes of CPAK classifica on do not lend themselves to kinema c alignment. Mechanical alignment should be considered for CPAK type V while adjusted anatomic should be considered for type II and Kinema c may be considered for types I, III, IV and VI. Kinema c alignment normally needs to take lesser cuts as the femur valgus helps in knee extension. Elliot Sappey-Marinier and Stefano Bini in 2023 have shown that unrestricted kinema c alignment can help in flexion deformi es to maintain the joint line and can prevent large cuts.

So, what has changed with technology and time? The basic principles of achieving a well-balanced anda well-aligned knee have not changed. What has changed is the means to achieve them. Technology has helped us understand these means better but we need not use technology every time in the OT to achieve the desired goals.To increase accuracy, most robotic systems rely on bony re-cuts rather than releases to finetune balance. This is something which has now percolated even for the regular workflow without technology. So, most surgeons will rely on a bony recut for finetuning balance rather than a more extensive but unpredictable soft tissue release. In a recent study from China on robotic TKRs, they found that 79% needed at least one re-cut to get balance5. So, the paradigm shift in present times has been the focus on sequential bony re-cut to attain balance mixed with limited soft tissue releases.

Technology assisted TKRs have helped us understand morphology better. Asian body types have not been found to corelate very well with even the CPAK classification. Mullaji and others published seven phenotypes of varus knees6and nine phenotypes of valgus knees7. Liu et al showed that functional phenotypes are better for planning than CPAK classification and that in the Asian population, adjusted mechanical and anatomic alignment with restricted kinematic alignment are better suited compared to kinematic alignment8.

Most present-day workflows for regular TKR are:

1. Pre-op assessment with a full-length film: CPAK grade and the joint contractures and laxities are noted. The primary alignment chosen is adjusted anatomic or mechanical.

2. Standard exposure would include a standard release for subluxationof the joint.

3. Cuts are taken according to standard alignment.

4. Further finer adjustments to achieve balance are made with bony cutsrather than unpredictable further soft tissue releases so that the end alignment remains within the realm of a “named” alignment.

The term “Functional” alignment is quite often used. It is interesting to note that the word“functional”when used for pain in medical terms would mean “without a cause” Is the word functional used because it helps and serves a function or is it because it is without a cause? I will leave it to the discretion of our erudite readers.

The plethora of alignments have now become a means to achieve “balance” in a knee rather than a specific alignment being an end-goal in itself!

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How do I plan and execute my knee? My journey from PS to CR

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joint replacement surgeon
Ahmedabad

The main goal of anany prosthetic implant is to restore joint function and to eliminate pain. Given the exponential increase in the number of knee arthroplasties, both due to an increase in the average life expectancy and to changes in lifestyle of patients, given prosthetic implants that could reproduce as betteras possible the normal knee kinematic and could endurefora long time is the main goal.

CRUCIATE-RETAINING (CR) DESIGN:
CR knee joint prosthesis is also called as "posterior cruciate ligament (PCL) retention prosthesis", which means that the posterior cruciate ligament (PCL) is preserved during surgery. And only anterior cruciate ligament is removed.

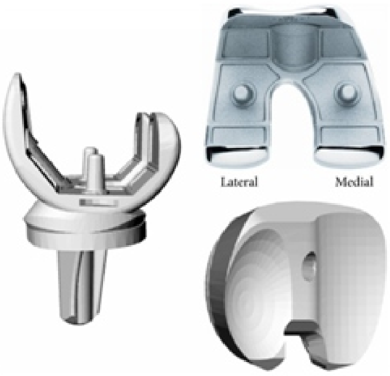


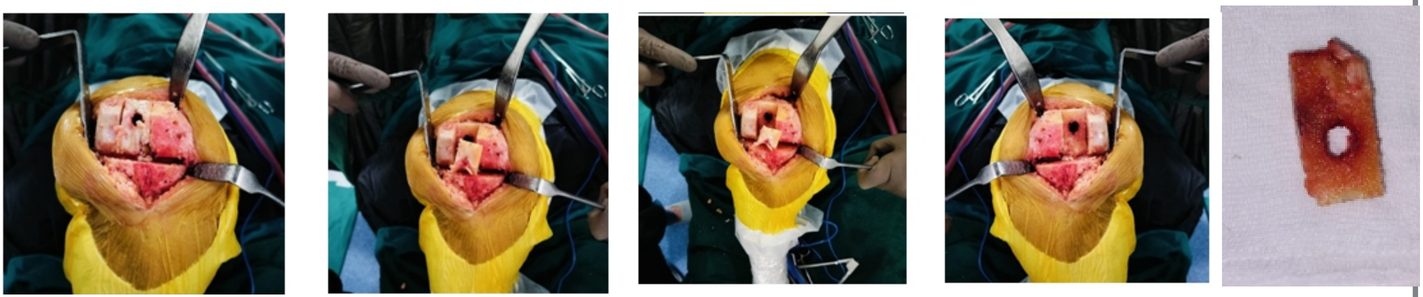
Fig. 1 Cruciate retaining (CR) design.

Role of posterior cruciate ligament (PCL):
The PCL functions as one of the main stabilizers of the knee joint and serves primarily to resist excessive posterior translation of the tibia relative to the femur. The PCL also acts as a secondary stabilizer of the knee preventing excessive rotation specifically between 90° and 120° of knee flexion. It stabilize the internal and external displacement, inside and outside angle and axial rotation.It maintain flexion space of the knee.Improved proprioception with preservation of native PCL. It maintain flexion space of knee joint and most importantly PCL plays an important role in PFR (posterior femoral rollback mechanism). When the posterior cruciate ligament is removed, the asymmetric stress act on the polyethylene pad, making it easy to wear. In most cases, the balance of ligament can be achieved without PCL resection (except for varus or valgus saddle > 20 degree).

Reason why we change our journey from POSTERIOR STABILIZED (PS) DESIGN to CRUCIATE- RETAINING (CR) DESIGN:

· We spare the PCL avoiding the intercondylar notch cut. The aim to preserve more bone as possible taking into account that in vast majority cases, there are young patients that will have the risk to require a further revision in future. Revision TKA is easy to perform with the preserved bone of femoral notch box after CR TKA.

· In a patient with small size femur and PS notch cut leads to possibilities of fracture which is always a great risk factor.



notch cut in PS TKA

With the PS knee(more with first generation) scar tissue gets caught in box as knee moves into extension named as patellar "clunk" syndrome. This can be avoided by CR knee.

Fig.3 patellar "clunk" syndrome

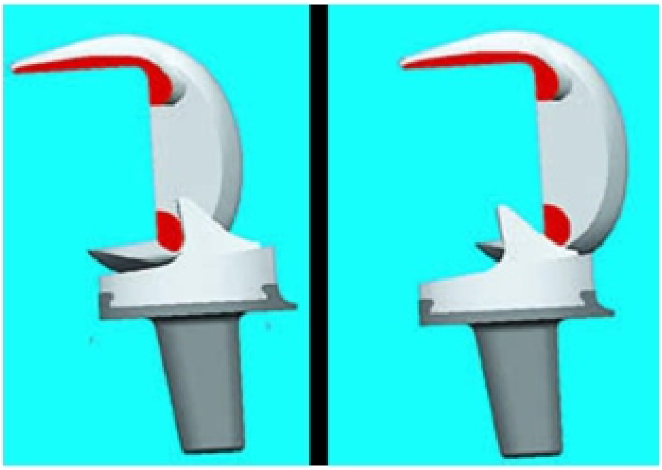


Fig. 4 cam jump

- CR knee avoids tibial post-cam impingement/ dislocation that may occur in PS knees. With loose flexion gap, or in hyperextension, the cam can rotate over the post and dislocate (i.e. CAM JUMP)

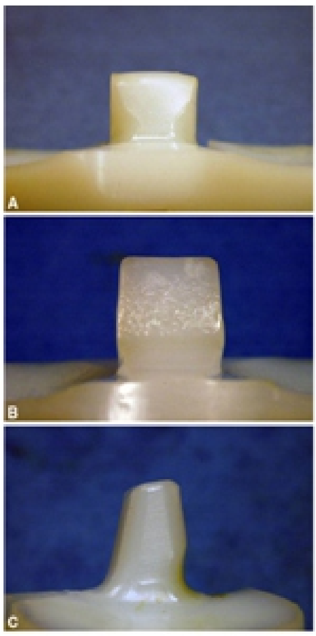


Fig.5Tibial post polyethylene wear

CR knee avoid tibial post polyethylene wear

CR knee improved proprioception with preservation of native PCL.

Surgical technique:

A standard midline longitudinal approach is performed with medial parapatellar arthrotomy and lateral patellar dislocation; the knee joint is exposed and the Whiteside line and the transepicondylar axis are marked (they are used as femoral rotational landmarks); the intramedullary femoral guide is drilled into the femur; a 9-mm distal femoral bone resection is performed with a valgus angle preoperatively planned
Distal femur cut: with the angel wing, you can appreciate the minimal resection in order to maintain the level of the joint line position.

For the tibial side, Hohmann retractors are employed to protect lateral and medial soft tissues (critical structures for a correct balancing); the tibial spine is removed using a surgical saw.
Then through the use of an osteotome, a bone island really closer to the distal insertion of PCL is circumscribed. We make use of the extramedullary tibial resection guide to align the tibial mechanical axis; an amount of resection equal to the thickness of the tibial arthroplasty component is measured on the less osteoarthritic plateau and tibial resection is performed bewaring not to get across the lateral and medial sides of marked bone island. The employment of the osteotome is an essential step: it allows to incise the posterior cortex avoiding during the tibial plateau excision the risk of avulsion and subsequent detachment of the PCL.

With these precautions, the tibial plateau is removed and the bone island can be carefully shaped through a nibbler to permit the placement of the posterior side of the tibial component.
The following step, with knee flexed at 90°, is defining the size and the position of the femoral component; we utilize an asymmetric spacer to perform a posterior condylar femoral resection perpendicular to the Whiteside line and in order to obtain equal medial and lateral gaps and to achieve the same space both in flexion and extension. By posterior referencing, 4-in-1 cutting block (set for the measured implant size and the rotational alignment previously evaluated) is placed and the anterior, posterior, anterior chamfer, and posterior chamfer cuts are performed.

Through the use of a gap spacer, the alignment and varus or valgus ligamentous balance are always tested both in extension and in flexion. The space between the femoral and the tibial cut surfaces should be within 1–2 mm of each other both in flexion and extension.
When the desired balancing and gaps are achieved, the femoral, tibial, and insert trial components of the correct size are inserted; we check the maximum extension and flexion and then stability and the patellar tracking in the full range of movement; usually, we do not perform patellar resurfacing but just remove osteophytes.
Once the tibial stem hole is created and the preparation procedure is completed, we perform a wash of the joint and then insert definitive cemented components and the polyethylene bearing of the previously evaluated size.

Consideration about surgical technique:

We think that to improve an already successful procedure, as TKA was well demonstrated to be, we need to look at small details.
In the debate between PS versus CR-TKA, the main reason in favour of PCL sacrifice is that balancing a joint with an intact PCL could be very difficult, especially in case of drastic deformities as severe fixed flexion, varus or valgus angulations more than 20° or considerable joint subluxation.
We think that the ability of the surgeon is critical to obtain a good CR replacement; technical

We think that the ability of the surgeon is critical to obtain a good CR replacement; technical difficulties lead to a longer learning curve, but using some tips and having cleared all basic science considerations explored, you can achieve good results even in the most difficult cases.
Taking these points into account, the first element to consider is that the goal of the procedure is both to place the TKA in neutral mechanical alignment and to obtain a knee stable in all range of movement. **In CR-TKA, the main criticism of the process is the preservation of the PCL and consequent balance of the spaces.**

Performing a CR-TKA, the **main criticism** of the surgical technique is that the distal attachment of the PCL is vulnerable to injury during the tibial resection; the distal attachment of the PCL is located posterior and distal to the tibial plateau, so the application of a protective device on the front is really useful to safeguard it.However, excessive bone resection from the proximal tibia (i.e., greater than 1 cm) or a large posteriorly sloped cut may anyway jeopardize the tibial attachment of the PCL and it can be prevented by using a pin of minimum 1.7 mm of lengthinfront of PCL defining the anterior side of the island that ensures a larger margin of safety . In addition, the creation of a bone island with the incision of the posterior cortex is really useful to avoid the avulsion of the ligament during the removal of the plateau.

The **second element** is that in order to accurately balance the joint, the surgeon can remove less bone from the distal femur (typically matching the thickness of the femoral implant which should be chosen to reproduce the A-P size of the back of native femoral condyles) in comparison to what would be done for a PS TKA.Due to the retention of the PCL in a CR-TKA, the flexion gap will remain smaller (in a range of 1.8–4.8 mm) than what would be created for a PS implant; therefore, the goal is to keep the extension gap small as well.

The **third element** is about the slope of the tibial cut: posterior slope opens the flexion space and this helps to obtain flexion without PCL recession. Therefore, a modest posterior slope (typically matching the patient's native slope within the range of 3–7°) may help to reduce tension on the PCL and this may facilitate knee flexion. If the extension gap is asymmetrical, it is necessary to perform a ligamentous release in order to obtain a symmetric space, and the gap size finally should be verified with a spacer block. Reflecting on the solution to achieve a symmetrical space in the flexion gap, it is really important to consider what type of instrument we are using: if we get the restoration of a neutral mechanical alignment in extension through the use of an intramedullary device for the femur and an external guide for the tibia, in our experience, the best instrument that helps us to get the correct rotation of femur in flexion is the flexion spacer; in fact, it is always referred to the tibial osteotomy (that regardless of surgeon accuracy should be 1° or 2° in valgus or varus deviation) and allows us to reach a parallel cut even in case of a severe lateral condyle hypoplasia thanks to its multiple choice in asymmetrical components (3°, 4°, 5°, 6°).

Once rotation is obtained, the following step is to determine the depth of the flexion gap. Not only does the flexion gap need to be rectangular (indication of rotation), but it also needs to obtain the same size of the extension gap. Through the use of the flexion spacer, the normal posterior condyle offset is recreated. Then, the depth of the anterior cut is not measured directly but rather determined by the size of the 4-in-1 cutting jig; it may be too shallow (this will cause overstuffing of the patellofemoral joint) or it may be too deep (this will cause notching).

A slightly lax PCL is preferable to one that is excessively tight, but an overly lax PCL can result in functional disability secondary to flexion instability. Balance of the PCL should be assessed after correction of any varus or valgus ligamentous imbalance. An excessively tight PCL will result in anterior translation of the tibia from beneath the femur, anterior lift-off of the trial polyethylene from the tibia tray in flexion, and/or displacement of the femoral component in flexion.

A useful test of therelative balance of the PCL is the so-called **POLO** (for PullOut, LiftOff) test introduced by Dr. Richard Scott. In this test, a trial reduction is done with a stemless tibial trial and a curved tibial insert. The PullOut portion of the test is done at 90° of flexion and confirms that the PCL is not too loose if the tibial insert cannot be subluxed (pulled out) anteriorly from beneath the femur. The LiftOff portion is done while putting the knee through a range of motion up to 120° and ensuring that the tibial insert does not look open (lift-off) in flexion, indicating that the PCL is too tight. Scott postulates that if the PCL is not too loose and not too tight, then it must be just right.

If the **PCL is excessively tight**, the tension can be decreased by several techniques. Increased tibial bone resection is only appropriate if the knee is tight in both flexion and extension. If the knee is tight only in flexion, increasing tibial bone resection will leave the knee lax in extension, resulting in symptomatic instability due to hyperextension or excessive varus-valgus play. If the knee is tight only in flexion, the posterior slope of the tibial cut should be assessed. The tibia normally has a 3 to 7°degree posterior slope. The amount of posterior slope cut on the tibia will be dependent on the prosthetic design. Some implants have an inherent posterior slope in the articular geometry and will require less posterior slope than knees with a flat geometry in the sagittal plane. Increasing posterior slope for the tibial resection will relax the PCL. Posterior tibial slope typically should not exceed 10° to avoid risk of injury to the tibial attachment of the PCL. Posterior cruciate recession consists of selective release of the anterior fibers of the PCL from their tibial attachment. Release of the anterior 10–20% of the PCL can often help achieve the correct soft tissue balance.

If greater than 75% of the PCL is released, some feel a PCL-substituting prosthesis should be considered. The concern in those cases is that the remaining 25% of the PCL fibers may rupture later with activity, leading to flexion instability. If the PCL is released or absent, the tibial tray should be more conforming because rollback does not occur. Hence, the surgeon should match the constraints of the soft tissue with the inherent constraints of the knee system being used.

A knee that is tighter in flexion requires one or a combination of maneuvers that include PCL release, downsloping the tibial resection, downsizing the femoral component, or additional tibial resection with distal advancement of the femoral component. A knee that is tighter in extension is usually corrected merely by added distal femoral resection.

Conclusion:

CR design offer normal knee kinematics and increased proprioception, preserves bone and greater stabilization of the prosthesis, with the PCL preventing anterior translation of the femur on the tibia. PS design does appear to support improved postoperative range of motion when compared with the CR design, while comparing in regards to clinical outcomes, there was no significant difference. Both designs give equal and good results. We preferred CR Knees in relatively young patients and patients with smaller knees as its bone conserving implant and PS knees in patients with Inflammatory arthritis, patient with severe varus or flexion deformity, when tibial cut is more than 10 mm and when intra-operatively findings suggestive of nonfunctional posterior cruciate ligament.

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Review of Literature on Dual Mobility Cups

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Dual mobility hip implants have garnered considerable attention in orthopedic literature due to their potential advantages in reducing the risk of dislocation following total hip arthroplasty (THA). Here's a **concise review summarizing the key findings and trends**:

Patient Selection: Patient selection is crucial when considering dual mobility implants. While they offer advantages in certain high-risk populations, not all patients may benefit from this implant design. Factors such as age, activity level, anatomy, and the presence of certain comorbidities should be carefully considered when deciding whether dual mobility implants are appropriate for a given patient.

Overall, the literature supports the use of dual mobility implants as a valuable option for reducing the risk of dislocation and improving functional outcomes following THA, particularly in high-risk patient populations. However, ongoing research and long-term studies are needed to further evaluate their safety, efficacy, and cost-effectiveness compared to traditional implants.

Surgical Technique and Learning Curve: Adequate training and experience in implanting dual mobility components are essential to optimize outcomes and minimize complications. Surgeons should be familiar with the unique characteristics and principles of dual mobility implants to achieve optimal stability and range of motion while avoiding technical pitfalls.

Reduced Dislocation Rates: Numerous studies have reported significantly lower dislocation rates with dual mobility implants compared to traditional implants, particularly in high-risk patient groups such as the elderly, those with neurological disorders, or those with a history of previous hip surgeries. The design of these implants, featuring a large articulating femoral head within a polyethylene liner within a metal cup, enhances stability and reduces the risk of impingement.

Dislocation in THR may lead to : Unplanned readmission after THR.Patient may require urgent treatment and treatment pathway can be long and complicated.It has higher morbidity and mortality score compared to THR patients.Also it gives cost burden to the patient.

Annual rate of dislocations after primary THA vary between 0.2% - 10% (Parvizi et al Recurrent instability after THA CORR June 2006).As High as 25% In Revision THA- Patel PD et al The dislocating hip arthroplasty :Prevention and Treatment J Arthroplasty:2007

The Cumulative risk –First month -1%,First Year Approx 2%,Continuously increases by 1% / 5 year period and amounts to approx. 7% after 25 years.(Garlik et al Hi arthroplasty Registery Annual report 2015,Berry DJ et al The cumulative long term risk of dislocation after primary charnley hip arthroplasty JBJS 2004). -

Long-term Outcomes: Long-term data on dual mobility implants are still somewhat limited, but emerging evidence suggests favorable outcomes in terms of implant survival, functional improvement, and patient satisfaction. Further long-term studies are needed to fully evaluate the durability and performance of these implants over time.

Review of Literature results:

Incidence of Dislocation -0.2%-10%: Early & late term dislocation risk after primary THAin the medicare population.Malkani et al… J Arthroplasty 2010, 39266 Primary THA 4.76 % (1868) dislocation80.6 % within first 2 years.The epidemiology of revision THA in US.Bozic et al [18] . JBJS 2009 Dislocation – most common cause of revision in US population.Phillips et al.. JBJS 2003/ 58521 Primary THA / 3.9% dislocation in first 26 weeks.Patel et al. J Arthroplasty 2007. Incidence rate 0.2-7% dislocation.Kosashvili Y et al. Canadian Jour Of surg 2014.Incidence rate 0.5-5%.[20]

1.A systemic review May 2020 .Ranga C Janker et al Ortho Tr Surg Res May 2020.549 DM and 649 Up cups included.1 (0.2%) dislocation in Dm.46 (7.1%) in UP cups.9 revision ,0 due to dislocation for DM.39 revision ,30 due to dislocation for UP. [25]Lower rates of dislocation and revision for dislocation in favor of DM cups:

DM cups –Effective solution to reduce dislocation in Primary THA.Outcomes of DMcomponents in THA.A systemic review.Darrith et Al. Bone Joint Journal 2018 [1]

2.Systemic review of DM publications. - 54 articles: 10783 Primary DM THA –Revision as endpoint,Mean follow up 8.5 years (2-16.5 yrs).Aseptic loosening 1.3% (142 hips).Intraprosthetic dislocation 1.1% (122 hips).Extra articular dislocation 0.46 %(41 hips).Overall survivorship of acetabular and DM components was 98%.Rate of intraprosthetic dislocation was low and associated with older designs.

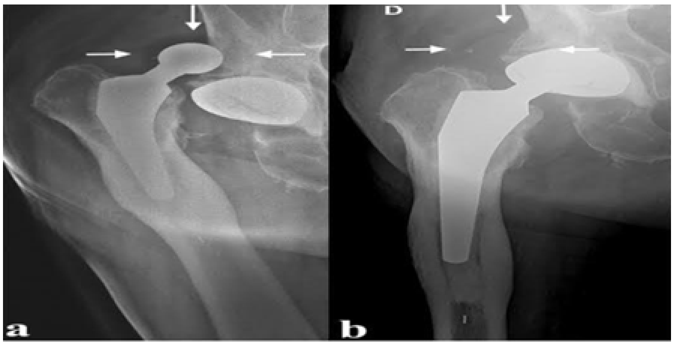
3.World Journal Orthop 2014 :De Martino et al : systemic review of DM publications.Systemic Review : 59 articlesAssesses rate of dislocation and IP dislocation.12844 primary DM THA.Mean age 68.8 years.Mean follow up 6.8 years.Mean rate of dislocation 0.9%.Mean rate of IP dislocation 1.3%.When compared with standard cups DM cups have decreased risk of revision for dislocation without increasing risk of osteolysis. [21]

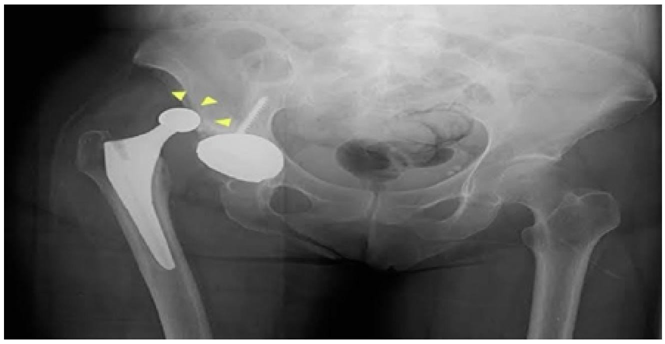
4.Low rate of dislocation of DM cups in Primary THA. Combes et al…..CORR 2013 : Report 2480 primaryTHA with Dm cups 1998-2003. Mean follow up 7 years (0.17-11 years).15 dislocation (0.6%).With 2 recurring (0.08%) and only one require revision(0.04%).[23]

5.Cohort study - 163 revisions with DM cups, J Arthroplasty 2018 :Mean age 68.7 years (34-92 years),63.2% female.Mean follow up 60.4 (+/-) 17.6 months. Overall dislocation rate 3.7%.Revisions conducted due to recurrent instability- Dislocation was 0%.7 years survivorship DM cups in revision THA – 96.1%(92.8-99.2%) [17]

6.Schneider et al.Orthop & Traumat : Surgery & Resesarch 2011: Series of 96 patients,Acetabular revisions with antiprotrusio cage and Dm cup.Mean age 69.9 years (34-95years).74% Female Mean follow up 41 months (1-101 months)10 dislocations -10.4%Intraprosthetic dislocation – 0.Survival rate at 8 year was 95.65 % (93.3-97.7%) [5]

7.DM Cementless cups in Recurrent THA dislocation : Leiber et al – Orthop Traumat Surg Res.2011:Restrospective analysis of 59 patients,Revision THA due to recurrent dislocation.Cementless DM cup,Implantation between 1995-2001.Mean follow up 9 years (8-11)..One early dislocation : treated conservatively & no recurrence.Crude dislocation rate 1.7%8 years survivorship with dislocation as endpoint 98% (95-100%).[24]





Results of DM in Femoral neck fractures : Mean dislocation rate of primary THA in neck femur fracture 10.7% - nearly 5 times higher than THA in OA Lorio et al –meta analysis CORR 2001.THA with DM is associated with lower dislocation rate as compared to conventionalSystemic review 2010-2019 published articles/23 studies,7189 patients / Mean age 77.8 yrs/ Mean follow up 30.9 month.Taraseviclus S et al .BMC musculoskelet Disord 2010,214 patients single centre study/1 year follow up – 8 dislocation (14.3) in the conventional THA group vs no dislocations in DM.Dislocation rates following conventional primary THA treatment of Fracture neck femur appear 7-15 times greater as compared to DM THA.[26]

Dual mobility Hip replacement : An attractive option for younger patients Comparative studyHSS April 2021:Comparision DM with Fixed bearing in two age matched groups. 136 patients,Mean age 48,3 years follow up,DM – No dislocationFixed bearings- 7 patients (5.1 %)dislocation – Revision surgery.DM -- Encouraging Results in Active High demand group. [24].Recent studies-Publication HSS : Dr Westrich 2021 : Study of 200 patients.DM implants in primary THAs , Age group of 45-70,5 years follow up.No dislocation rate with DM.

National Joint registery – Us data 2022 : Compiled data of outcomes of patients who had DM hip replacement at HSS and other 3 hospital,Mean age 67 years,Follow up 5-7.9 yearsNo dislocationsRadiology- No loosening [24].

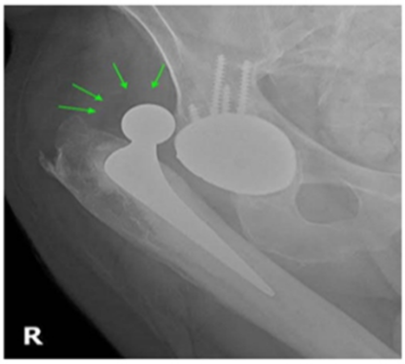
Can DM cups prevent dislocation without increasing revision rates in primary THA : A systemic review May 2020 .Ranga C Janker et al Ortho Tr Surg Res May 2020.549 DM and 649 Up cups included.1 (0.2%) dislocation in Dm.46 (7.1%) in UP cups.9 revision ,0 due to dislocation for DM.39 revision ,30 due to dislocation for UP.Lower rates of dislocation and revision for dislocation in favour of DM cups.DM cups –Effective solution to reduce dislocation in Primary THA. [25]

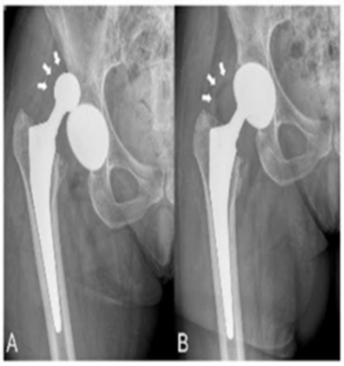
Our own experience review of 78 patients with Dual Mobility Cups : Single center and single surgeon from 2011-2024 a total 84 THA in 79 Patients : 83 Primary THA & 1 Revision THA (For failed proximal femur nail hip fixation).41 Female & 38 male : 50 cases below 60 years of age 28 cases below 50 years of age.No cases of disclocation, looseing, infection, osteolysis or revision. Significantly improved hip scores.Very encouraging results in patients below 55yrs of age.

Improved Range of Motion: Several studies have demonstrated that dual mobility implants can lead to improved range of motion compared to conventional implants. This can be particularly beneficial in patients requiring increased hip flexibility for daily activities or certain sports.

Complications and Concerns: While dual mobility implants offer advantages in terms of stability, concerns have been raised regarding potential complications such as liner wear, osteolysis, and intraoperative fractures. However, modern implant designs and materials have aimed to mitigate these risks, and careful patient selection and surgical technique can help minimize complications.Restoration of Hip Biomechanics includes restore the center of rotation,restore offset,restore limb length and abductor integrity.

Complication majorly found : Intraprosthetic dislocation , PE wear and Osteolysis , Aseptic loosening of the acetabular component.





Cost-effectiveness: There is ongoing debate regarding the cost-effectiveness of dual mobility implants compared to traditional implants. While initial costs may be higher, some studies suggest that the reduced risk of revision surgery and associated healthcare costs due to dislocation may ultimately make dual mobility implants a cost-effective option, particularly in high-risk patient populations.

The economic ramifications of THA complications are staggering – with the cost of revision often exceeding 50,000 US dollars prior to consideration of additional costs such as post-acute hospital care.1 Furthermore, the mean cost for revision surgery in the UK for aseptic cases is £11,897, the full costs of which are often not fully reimbursed by current National Health Service (NHS) hospital tariffs.43 The significantly reduced revision rates exhibited by contemporary DMC suggest DM may represent a far more cost-effective modality comparative to standard THA bearings. In France, using Markov modelling with determination of the incremental cost-effectiveness ratio (ICER), the direct healthcare costs of 80,405 patients who had undergone THA were analysed over 4 years. Using a conservative relative risk of dislocation of 0.4 for DM THA versus standard bearing THA, when considering the costs resulting from readmission and rehabilitation, the authors determined DM THA could be expected to save 283 Euros per patient. This result translates into a major economic impact, with an estimated cost-saving of nearly 39.62 million Euros if DM THA was performed for all 140,000 primary THAs carried out in France annually.44 Moreover, in Barlow et al's Markov analysis of the lifetime cost-effectiveness of differing arthroplasty modalities, DM THA demonstrated absolute dominance over standard bearing THA – with lower accrued costs (US$39,008 versus US$40,031) and higher accrued utility (13.18 versus 13.13 quality-adjusted life years).45 Likewise, in patients with spinal deformity, Elbuluk et al illustrated that DM was cost-effective when dislocation rates were reduced to 0.9%, without including longer-term economic implications associated with dislocation such as revision surgery or loss of income.46 Therefore, although longer-term financial analysis is required, early results suggest DM represents a cost-effective modality for primary THA.

Conclusion: Total hip arthroplasty is one of the most successful surgical procedures – reducing pain and providing functional improvement to enhance patients' quality of life. However, it is not without risk. Total hip arthroplasty instability is a disabling condition and may remain the most common indication for revision THA.The DMC has always exhibited excellent results in reducing THA instability.Scepticism regarding first-generation DM centred on complications unique to the DMC such as IPD.Implant modifications including use of highly cross-linked, durable PE and a smoothcylindrical femoral neck have all but eliminated IPD in the contemporary DMC.In multiple short-term studies, DM THA demonstrates a statistically significant reduction in dislocation rates comparative to standard bearing primary THA.These results have been particularly promising in high-risk patient populations andfemoral neck fractures – where low dislocation rates and improved functional outcomes are a recurrent theme. From an economic perspective, DM is equally exciting – with research demonstrating lower accrued costs and higheraccrued utility comparative to standard bearing THA.Despite this, longer-term clinical evidence and higher-qualityprospective comparative studies are required to strengthen current research. DM may well represent the future gold standardfor THA in high-risk patient populations and femoral neck fracturebut due diligence on their long-term performance is needed before recommendations for their widespread use can be justified.

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ACETABULAR DEFECT MANAGEMENT IN COMPLEX PRIMARY / REVISION HIP ARTHROPLASTY: CUSTOMISED AUGMENTS & CUSTOMISED ACETABULAR CUPS

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Introduction:

With increasing numbers of primary total hip replacement (THR), there has been a substantial increase in revision total hip replacement (RTHR) surgeries. RTHR are complex joint reconstruction surgeries involving significant cost, expertise and infrastructure.

However, component loosening stands out as a major complication and a primary contributor to the rising global burden of revision surgeries over time. During such revisions and sometimes even in certain complex primary cases, the surgeons have to deal with moderate to severe bone loss on both acetabular and femoral side.

The challenge of complex osseus defects becomes a crucial and critical issue. Large acetabular defects cannot be always treated with standard implants. Conventionally, the problem was solved using biological means like bone grafts or by using specific implants like Anti protrusion cages, Jumbo cups, Muller rings and saddle prosthesis depending on the nature of defect.

Off-the-shelf implants come in standardized sizes and shapes. In large and complex defect cases, these implants may not adequately restore the patient's unique anatomy. This can lead to problems. The commonest is Instability. The implant may not fit snugly into the defect.

Customized 3D Printed trabecular implants for Paprosky IIIB/ Parosky IV defects have shown promising results in terms of improved patient outcomes and reduced complication rates.

The advantage of the process includes customized approach to the problem, reduced inventory, better osteointegration potential, less donor site morbidity, near total anatomical reconstruction and predictable, better patient results.

As technology has advanced and infrastructure has improved, the availability and the cost of 3D printing has become more affordable and accessible.

The main aim of this article is to understand our approach to complex defects that cannot be managed with any off the shelf implants and how it is accessible even in the small towns of Gujarat.

To understand the process, let us walk through how to plan for such a case.Hereby, there are 2 such cases treated for Complex acetabular defects. We would like to guide step by step approach to any such case with complex defects.

CASE 1.

ü 55 years / female

ü Primary Total hip arthroplasty was done in 2017.

ü 6 month post op x-ray was s/o loosening of acetabular component. However, patient continued to walk on that leg, but with pain and presented 2 years later.

CT scan shows massive acetabular defect equivalent to Pelvic discontinuity. Probably a conventional cage would not hold and a custom implant would be necessary.

The question would be how to proceed from here, once a decision for considering a 3d printed custom implant is taken, the CT scan, with 0.5 mm slicing is preferred for accurate measurements.

There are numerous companies working in this field in Gujarat and a larger number of companies working Pan-India. One such medica device company is Orthotech India Pvt LTD. Valsad.

Most of them have an online presence and the raw CT scan needs to uploaded as recommended viz

3d.osteograte@gmail.com

CT SCAN UPLOAD & PROCESSING:

The companies have a back-end team of biomedical engineers who take the CT scan to create 3D bone models using special software. This process when automated with artificial intelligence may take a few minutes but for most complex revision cases, manual segmentation may take a few hours.

This refined data undergoes segmentation and surface preparation processes to delineate the area of interest, remove unwanted structures and create the surface mesh. This data thus provides detailed 3D images of the patient's anatomy and pathology which are essential for assessment of bony defects, availability of patient bone stock, quality of bone and even nearby neurovascular structures which are crucial for designing the custom implant. Orthopaedic surgeon input is required and asked for as and when needed.

The biomedical engineers then start designing the custom implant with orthopedic consultants attached to the company as well as taking the treating orthopedic surgeon's opinion.

Various parameters pertaining the host bone quality and implant (Pore size and Topological optimization) are assessed and decided.

Ø Before printing the actual implant, the digital design is validated through simulation (ANSYS software).

Ø Finite Element Analysisis done to ensure that the implant will provide the necessary stability and range of motion once implanted.

Ø Usually, a 3D printed plastic prototype of the bone with the defect and the proposed implants are sent to the treating surgeon for validation before 3D metal printing of the final implants.

3D printingis carried out on specialized machines using Biomedical grade titanium powder. This is required to be imported under strict licensing. One such FDA approved machine DMP FLEX 350 From 3D SYSTEMS (USA) is in Gujarat at Valsad, renowned medical device company with all required compliances. A lot of engineering firms also have 3D metal printers in Gujarat, however medical implant printing is preferred by compliance in medical device company only.

A vendor with experience in orthopaedic applications is always preferred. The custom implant is 3D printed using a specialized additive manufacturing process, such as selective laser melting (SLM) or electron beam melting (EBM). This process fuses powdered metal together layer by layer to create the implant's final shape. While several materials like stainless steel, aluminium, Titanium, may be potentially used, the choice of material depends on the specific requirements of the application. Given its material property Titanium is the preferred implant currently.

Off the shelf implants are made by CNC (Subtractive manufacturing) where a rod or plate is cut to required size and shape. Customised 3d printed implants are made by Additive manufacturing where biomedical grade titanium powder is layered by sintering and laser is used. This enables freedom of design, customization, and creation of trabeculae lattice which is not possible by CNC machine. This lattice, trabeculae create interface for osteointegration.

The printed implant undergoes rigorous quality control and inspection to ensure it meets the design specifications and medical standards. This may include dimensional accuracy, surface finish, and structural integrity tests.

Post-processing steps, like surface smoothing or coating, may be performed to improve the biocompatibility of the implant and promote bone integration.

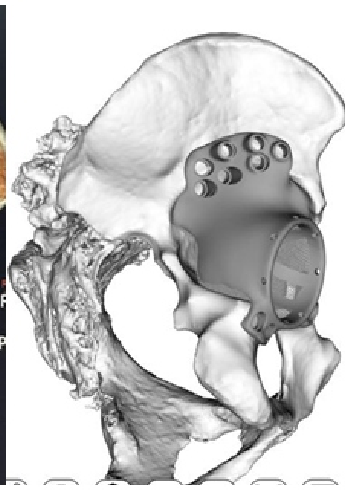
Surgeons should pay attention to the fact where the implant is 3D printed, sterilized, and packed with proper batch details.

Custom 3D printed jigs may be provided with the implant for placement and trajectory of screws. The surgery is made convenient and easy as entire pre operative planning is done on a software.

The operative steps then are fairly simple.

Ø After exposure, the 3D printed implant is placed directly in the defect and the 3D printed jigs make application very simple.

Ø The orientation, inclination and version would get autocorrected as the 3D printed implant locks into the defect, and it is built as per the dimensions of the native hip. The post-operative protocol would be the standard followed for any joint replacement at the institution.



3D printed digital image and 3d printed model with custom implant trial

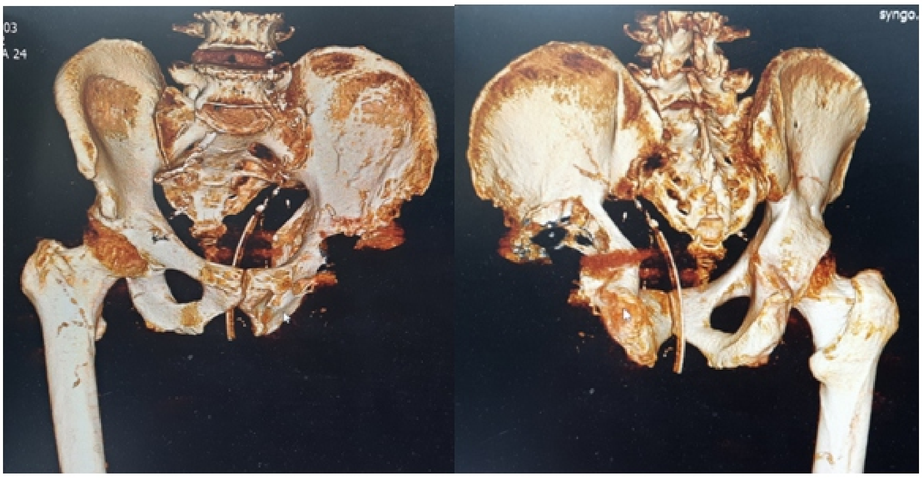
Trial of implant over Bone Model, screw size and placement confirmation pre operatively.

Post operative Xray

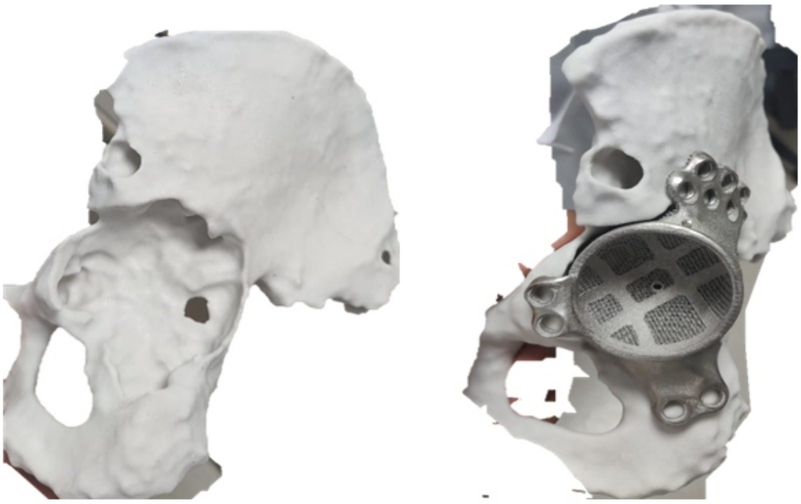
CASE 2

- 74 years / Male
- Operated for left side primary total hip arthroplasty 18 years back.
- Was able to walk without support after that.
- Had h/o fall from standing height in September 2022 followed by inability to walk on left leg.
- 2 stage revision was done (cement spacer followed by revision total hip replacement) in view of infection.
- At 2nd stage, acetabulum was reconstructed using customized implant.

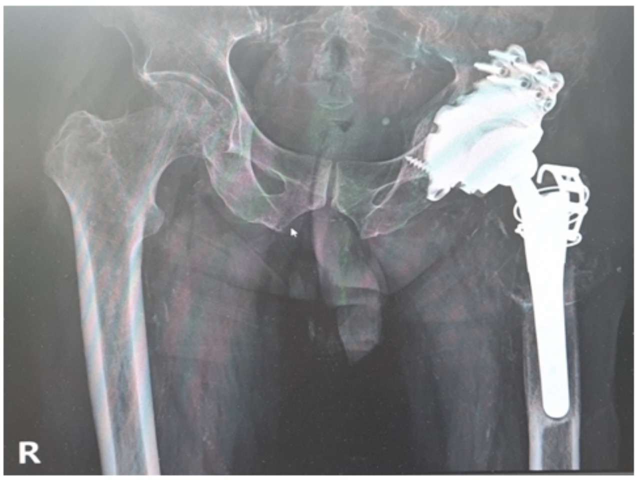
Pre-operative CT scan showing severe acetabular defect



3D printed hemipelvis BONE model and trial of custom-made implant over that



Post operative Xray



ADVANTAGES OF CUSTOMISED 3d PRINTED ACETABULAR CUP AND AUGMENTS

Custom 3d Printed implants have gained popularity in certain scenarios due to their advantages over traditional methods. They are cost effective and the turnaround time is generally less than 3 weeks.

1. Surgical planning and surgical simulation, 3d prototype

3D-printed anatomical models offer a valuable alternative, allowing surgeons to better understand individual patient anatomy and practice surgical approaches, procedure feasibility, and implant size and placement

2. Precision in Placement with inbuilt Centre, Inclination and version.

Custom implants are designed based on the patient's specific anatomy and pathology which allows for an exact fit of the implant and optimal alignment. This customization can lead to optimised outcomes and reduced complications. Metal 3D printing allows complex geometries that traditional manufacturing methods find challenging and sometimes impossible to create mainly creating trabeculae interface for osteointegration.

A 2013 study by Won et al. demonstrated the success of THA in 21 complex hip cases using RP models. In 80.9% of cases, the chosen acetabular components closely matched the predicted size. Follow-up assessments showed stable components with no signs of wear or bone problems.

3. Reduced surgery time & Blood loss.

Custom implants often require less intraoperative adjustment and manipulation, which can shorten surgery duration. Shorter surgeries can be associated with fewer complications and a quicker recovery for the patient. This can ultimately improve surgical efficiency, reduce blood loss, decrease surgical time and reduce exposure to harmful radiations intra-op.

4. Minimized donor site morbidity

Custom implants eliminate the need for donor site grafting.

5. Faster healing and recovery due to enhanced fixation- osteointegration

Custom titanium implants can promote faster bone healing since they are designed to fit precisely, reducing the need for extensive bone remodelling- trabeculae interface. Highly porous structures and patient's matched bone specific biomechanical properties imparts 3D printed implant enhanced stability, bone ingrowth, osteointegration and neutralizing capacity to stress shielding, and hence prevent aseptic loosening.

6. Predictable and improved outcomes

Custom implants are created based on preoperative imaging and planning which allow surgeons to predict and control the surgical outcome more precisely and efficiently. The primary clinical advantage of 3D printed implants is to achieve successful and over-lasting bony fixation and to re-establish joint biomechanical function.

7. Complex reconstruction

In cases of complex primary or revision and tumour surgeries, custom implants offer the best solution when traditional implants with or without bone grafts fail.

8. Preservation of healthy bone

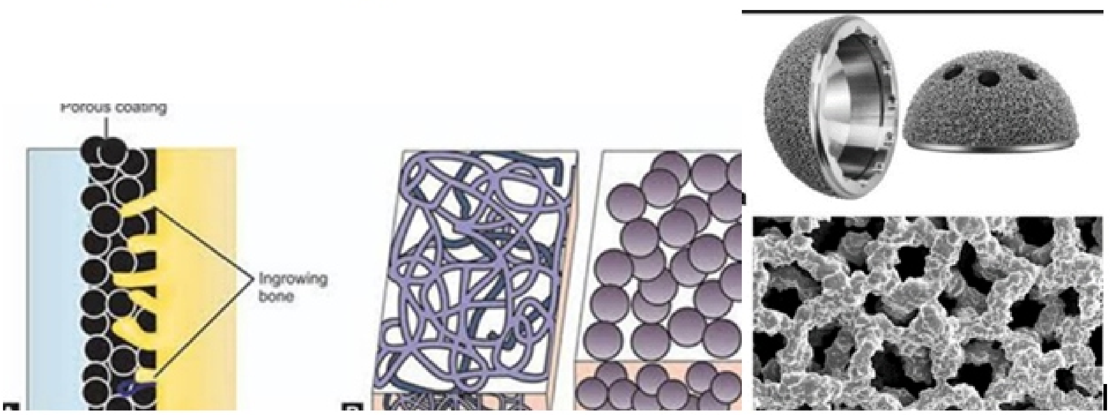
Custom implants can be designed to precisely replace only the damaged or deficient bone, preserving healthy adjacent bone, which is not always possible with bone grafts.

9. Reproducibility

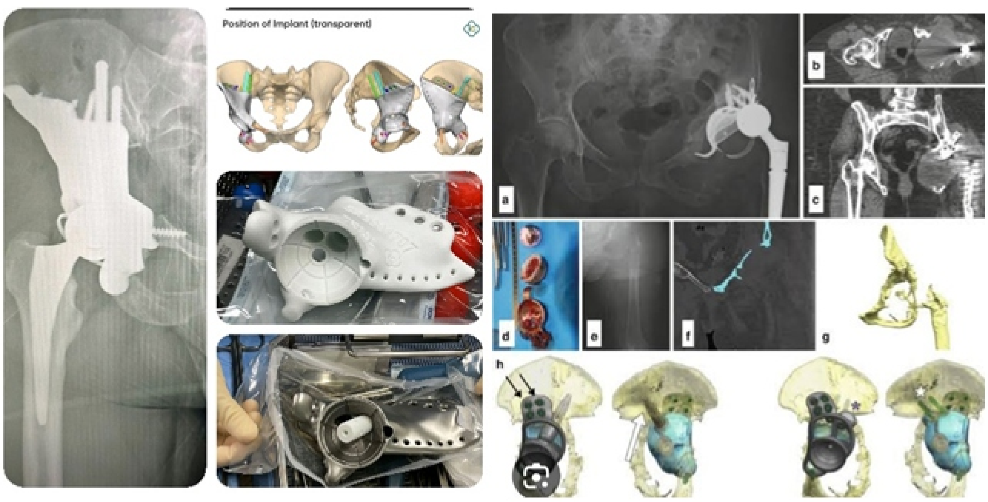
Once the design of a custom implant is created and tested, it can be easily reproduced for other patients with similar needs, streamlining the surgical process.

10. Technological advances

Advances in 3D printing and computer-assisted design (CAD) have made custom implant production more accessible and cost-effective. Materials like trabecular titanium have mechanical properties alike human trabecular bone and such materials can only be produced by advanced Rapid prototyping or 3D printing technology. The incorporation of trabecular titanium material into a hip prosthesis allows for the creation of a prosthesis that combines mechanical stability, biocompatibility, and the promotion of osseointegration.



Porous coating versus Trabecular osteointegration

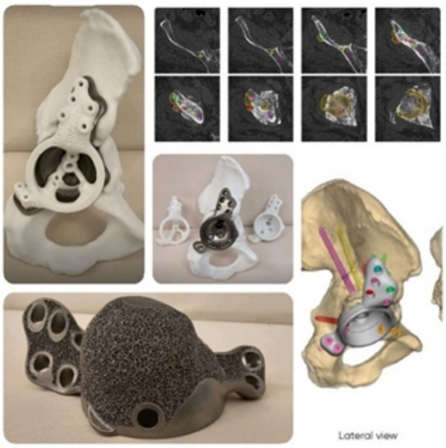


3D Printed Prototype and Implants

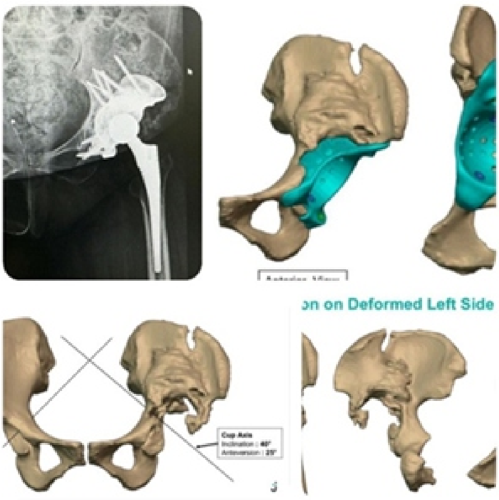
CONCLUSION

Thus, in cases of complex acetabular defects in complex primary, or revision hips, evaluate the patient data from x-rays, CT scan properly, and think customization in case you are sure that the off the shelf options available might not give optimized results and outcome. Think 3D printing solutions as the best option, for reconstruction of precise anatomy, optimised patient outcomes.

3D Printing Machine and Lattice structure / Trabeculae cup



Customised 3D printed Acetabular cup for Traumatic Pelvic Defect



Triflange customised Cup for complex defect.

APPENDEX

METAL PRINTING

- ORTHOTECH INDIA PVT LTD. VALSAD
- 3D INCREDIBLE, PUNE
- SURGIWEAR, SHAHJANPUR UP
- IIT BOMBAY, BETIC, Mumbai.

DESIGN & INNOVATION

- AAROGYAM 3D, VAPI
- JAJAL MEDICAL, BARODA

HOW DO YOU MANAGE LIMB LENGTH WITH POSTERIOR APPROACH?

Dr Javahir Anant Pachore,

Dr Vikram I Shah

INTRODUCTION

Limb length discrepancy (LLD)following total hip arthroplasty (THA) is a well-known complication, with an incidence ranging up to 27%, and it can vary from 3 mm to 17 mm [1,2]. LLD after THA is correlated with patient dissatisfaction, pain, neurological complications, and is one of the leading causes of malpractice claims against arthroplasty surgeons [3,4]. Nearly one-third of healthy individuals may exhibit LLD, ranging from 5 mm to 2 cm [5,6]. This difference in limb length can be either functional or structural. While there are various methods available to reduce the likelihood of LLD, none can guarantee a 100% success rate. Although new robotic systems show promise in minimizing LLD, not every surgeon has access to this technology. The threshold of LLD acceptable is not clear in the literature. To mitigate this complication, surgeons should focus on preoperative counselling, thorough preoperative clinical examination, radiographs with magnification markers, templating, intraoperative measurements, and precise surgical techniques.

LLD is broadly categorized into structural (true) and functional (apparent) types. Structural LLD results from the loss of osteo-articular components, while the functional LLD is due to soft tissue contracture and pelvic obliquity. Certain patients are at a higher risk for developing LLD. Among them are those with developmental dysplasia of the hip (DDH), severe arthritis leading to destruction of the femoral head, coxa vara, protrusio, non-union, previous excision arthroplasty, childhood physeal arrest, and so on.

Patients often perceive sensations that the operated limb is longer [7]. This sensation is mainly attributed to soft tissue contracture and pelvic obliquity. However, it typically resolves over time and should be addressed through preoperative counselling.

PREOPERATIVE EXAMINATION

The basic clinical examination is crucial and should be thoroughly documented. Gait analysis provides the initial indication of shortening, characterized by a short limb gait. The second marker is spinal examination, which can reveal compensatory scoliosis. In cases of abduction contracture, scoliosis tends to occur on the opposite side, whereas it reverses with adduction contracture. The third parameter involves evaluating fixed deformities, distinguishing between abduction and adduction deformities based on the level of the anterior superior iliac spine. Lastly, it's essential to assess whether the pelvis is fixed or mobile. Both apparent and true measurements should be documented.

RADIOLOGY

Radiological assessment is critical and reliable, particularly in the absence of gross deformities. A standing radiograph with a block provides more dynamic information regarding shortening [9]. Several measurements are essential for surgical planning, including the location of the teardrop, inter-teardrop line, inter-ischial line, vertical offset, horizontal offset, distance from the tip of the trochanter to the center of the head, and acetabular offset. [fig 1]

PREOPERATIVE TEMPLATING

Preoperative templating requires high-quality radiographs with markers for magnification. Since most available templates are magnified to 20%, your marker should be magnified to the same extent [10]. During acetabular templating, the component should be positioned 5 mm inferior and lateral to the teardrop, indicating the inferior aspect of the implant [11]. The cup angle should be inclined to approximately 40-45 degrees to the symphysis, ensuring adequate superiolateral cover. [fig 2] When encountering a medial osteophyte, the template should be adjusted medially to cover the bony acetabular coverage. Restoring the native acetabular center of rotation is crucial to avoid LLD and maintain offset.

For the femoral component, the center of rotation on the femoral head can be identified using Moes circles, especially in deformed femoral heads. The level of the neck cut significantly affects vertical and horizontal offset. [fig 3] Patients with coxa vara may require a deeper neck cut to align the center of the head with the tip of the trochanter, while in coxa valga, the neck cut should be reduced to maintain vertical offset which plays a significant role in LLD, and surgeons often measure it from the tip of the trochanter to the center of the femoral head. There may be some marginal differences between preoperative templating and intraoperative implant sizes due to various factors. Recently, 3D templating and planning software have been introduced [12].

SURGICAL TECHNIQUE FOR POSTERIOR APPROACH

Performing surgery in the lateral decubitus position poses challenges in quantifying limb length discrepancy (LLD) because radiology use is cumbersome. A standard posterior approach involves detaching the capsule and external rotator as a single flap from the intertrochanteric line. Three methods for LLD are employed, with the Ranawat method is preferred for its accuracy, as measurements closely align with the center of rotation.Before dislocation, a Steinmann pin is placed at the posterior infracondylar groove, perpendicular to the table, touching the greater trochanter. [fig 4]Limb position consistency is crucial, with any changes affecting measurements. The limb is kept in 10-15 degree flexion, neutral rotation, and neutral abduction/adduction, with marking done on the greater trochanter before dislocation. Hip dislocation is achieved by adduction, internal rotation, and flexion.

After dislocation, vertical and horizontal offset measurements are taken. Deformities in the femoral head can affect vertical offset accuracy, which can be mitigated by placing a trial cup of adequate size. The intertrochanteric area is drilled around the centre of neck which gives a fixed point for vertical offset measurement. The other method is to mark it with marker pen. The neck cut is carried out by putting the trial broach with standard modular neck which matches the centre of femoral head.This will create the vertical offset. It's advisable to keep 2-3 mm more neck than excessive neck cutting. With the advancements in modularity, adjusting neck length has become more feasible. Before neck cutting, horizontal offset from the stump of the piriformis or piriformis fossa to the centre of the femoral head should be measured. The relationship between the tip of the trochanter and the centre of the head should be duplicated.

After neck cutting, acetabulum exposure follows standard procedure. Identification of the transverse acetabular ligament (TAL) is crucial for estimating acetabular anteversion. A parallel line is drawn in relation to TAL just above the superior part of incision with marker pen. Reaming should be performed perpendicular to a line parallel to the TAL, maintaining natural anteversion. The reamer angle should be 40-45 degrees to the table plane. The trial cup's inferior margin should be parallel to the TAL, ensuring its visibility, which reduces LLD risk.A distance between the TAL and the cup's inferior margin indicates superior cup placement contributing to LLD. If the TAL isn't visible after trial cup placement, it suggests vertical cup placement, potentially leading to instability. Excessively inferior cup placement can lead to lengthening and loss of ischial bone stock.

After satisfactory trial cup placement, the definitive cup with a trial liner can be used. Femoral preparation begins with lateral entry in the piriformis fossa using a box chisel to avoid varus placement. Sequential broaching depends on the femoral implant type, with anteversion aligned with the tibial shaft at 10-15 degrees if possible. Retroversion in the femoral component is not accepted. Another guide for anteversion is aligning the broach border with the posterior border of the neck, corresponding to the patient's normal anteversion.Broach stability should be tested, followed by mounting the trial head for vertical and horizontal offset measurement, as documented before neck cutting. After verifying vertical offset, trial reduction is performed, followed by the Ranawat infracondylar test using a Steinmann pin. As per preoperative planning of LLD, achieved length after trial reduction should be confirmed. The difference between the two markings indicates the achieved length which is measured. [fig 5] If patient has a preoperative shortening of1 cm, after the trial reduction the second mark should be 1 cm below first mark, which indicates that we have achieved accurate limb length.After the satisfactory reduction all stability tests are conducted. If more than 1 cm of lengthening is attained one should keep the knee in flexion to avoid sciatic stretch. Sciatic stretch is carried out by palpating the sciatic nerve with one hand while gradually extending the knee. If the sciatic nerve feels more taut, hip re-dislocation and neck length reduction are necessary. Limb position during marking should remain consistent with before dislocation.

Sarin et al. reported that a 10-degree change in adduction and abduction can result in a 17 mm limb length measurement error. The Ranawat technique is not suitable in the presence of large inferior osteophytes. Ranawat's method is more reliable due to its proximity to the centre of rotation, with minimal reported LLD error of 2.6 mm in postoperative radiographs.

The second method is the stitch method. Before hip dislocation, a firm stitch is taken on the skin and subcutaneous tissue above the superior border of the incision. The length of the stitch is measured from the superior stitch to the tip of the trochanter. The limb is then kept in neutral rotation, neutral flexion, extension, and neutral abduction/adduction. This limb position should be maintained after trial reduction. This method, recently described by Vijay Bose under the heading of soft tissue balancing, is referred to as a coaxial stitch.[14] [fig 6]

The third method is the calliper method. A Shanz pin is fixed in the supra-acetabular area in a bi-cortical fashion to ensure stability. A calliper is then attached to the Shanz pin, and the distance is measured from the Shanz pin to the tip of the trochanter with the limb in a neutral position before dislocation. The same manoeuvre is used after trial reduction to achieve the desired length.[15]

Intraoperative radiographs or fluoroscopy have also been used for limb length measurements [16]. However, this approach is not practical in the lateral decubitus position with a posterior approach.

Navigation and robotic systems have a promising future role in limb length measurement and component position, but their availability is limited to few centres [17]. Digital smart tools based on infrared-based optical tracking technology have reported excellent accuracy compared to radiographic measurements.

Final confirmation of LLD is clinical which may not be accurate due to various factors as mentioned earlier but radiology will give fair degree of accuracy of LLD. (Fig 7 & 8)

TREATMENT OF LLD

Functional and structural LLD less than 1 cm typically does not require treatment or can be managed with a shoe raise [6,18]. However, functional LLD should not be treated with a shoe raise for a minimum period of 3 to 6 months. Ranawat and Rodriguez reported pelvic obliquity in 14% of patients, which resolved without treatment within 6 months of surgery [2]. Patients with neurological compromise post-surgery and obvious LLD may require surgical intervention [19]. Lengthening exceeding 2.5 cm can lead to lateral popliteal palsy, while exceeding 4 cm can result in sciatic palsy [20]. Revision surgery will depend on the malposition of individual components. In most cases, the femoral component can be addressed due to the availability of modular options [21].

KEY POINTS

- LLD is frequently seen in patients undergoing hip replacement.
- LLD can be structural or functional.
- LLD more than 2 cm can cause symptoms of back pain, abnormal gait, and instability.
- Preoperative counselling, clinical examination, good radiographs, adequate templating and intraoperative measurements can reduce the magnitude of LLD.
- Less than 10 mm of LLD does not require any treatment.
- Neurologic deficit with LLD requires emergency surgery to rectify.
- Ranawat method is adequate for the posterior hip surgeons.

SUMMARY

Preoperative clinical assessment of LLD using the tape method or block method, along with good radiographs with a magnification marker allowing measurement of LLD, vertical offset, and horizontal offset, is crucial. Adequate templating, whether physical or digital, can help reduce surgical errors. During surgery, intraoperative measurements of vertical offset, horizontal offset, and proper neck cut with trial implants are essential. Utilizing a familiar intraoperative measurement method is recommended. Consistency in limb positioning before dislocation and after trial is crucial, as all intraoperative measurements have one fixed point and one mobile point. LLD less than 10 mm typically does not require treatment, and reassurance is key to reducing malpractice claims. Patients with neurological complications should be promptly addressed.

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SPINOPELVIC INSTABILITY AND ITS IMPLICATIONS ON TOTAL HIP ARTHROPLASTY

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INTRODUCTION

The spine and pelvis work together in a biomechanical co ordination for upright posture and bipedal gait, which puts considerable and unique demands on the human body. [1,2] The femur and acetabulum also contribute in this. The acetabular orientation and sagittal balance/lumbar lordosis is influenced by this orientation.

Discrepancy in the spino-pelvic parameters such as pelvic tilt, sacral slope and pelvic incidence leads to spinopelvic instability. Measurements of these parameters before total hip arthroplasty is recommended to overcome implant related complications.

Evaluation of Spino-Pelvic parameters

Lateral views of radiographs of pelvis showing the lower lumbar spine, sacrum, hip joint with proximal femur are taken in standing and sitting position. Then different angles are measured as given below.

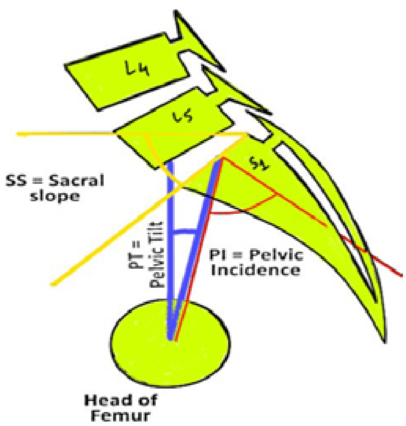
Pelvic incidence (PI) is a fixed angle, measured by drawing one line from the center of S1 end plate towards the center of the femoral head and another line from the center of the S1endplate to the bicoxofemoral axis.

Pelvic tilt (PT) is an angle formed by using the same arm that starts from the center of the S1 end plate to the center of the femoral head and another line that projects vertically from the center of the femoral head.

Sacral slope (SS) is the angle between the S1 endplate and the horizontal line drawn perpendicular to the vertical line between the S1 endplate and center of the femoral head.

These three angles are balanced in the equation PI=PT+SS [3,4]

According to this when the hip moves from standing to sitting position in combination with the pelvis and spine,the bending of the hip is about 55-70 degrees, posterior tilt of pelvis increases to 20 degrees and the lumbar lordosis decreases approximately 20 degrees.[5] The posterior tilt of the pelvis influences the sacral slope and reduces it in the same amount [2] and each degree of rear-ward movement of the pelvis [pelvic tilt (PT) increase] results in a 0.7 to 0.8 degrees of Acetabular anteversion [6,7



SPINOPELVIC PARAMETERS IN NORMAL STATE(Figure-1)

There is a significant variability in static and dynamic spinopelvic parameters even in healthy individuals without any spine or hip abnormality. The contribution of femur, acetabulum, lumbar spine and sacrum can be considered in conjunction for the movements of the hip joint contrary to the shoulder abduction arc where the scapulothoracic and glenohumeral movements are considered separately.

The femoroacetabular joint contributes to two thirds of the sagittal movements and one third is contributed by the lumbar spine. The posterior tilt of the pelvis is dependant on the femoro-acetabular flexion when moving from standing to relaxed seated position which increases the acetabular anteversion. A greater pelvic roll back is required to adopt relaxed seated position.

As part of the kinetic chain the lumbar lordosis is dictated by change in the sacral slope.[8,9] Maximum sagittal flexion is achieved by the body when trying to transition to a flexed seated position. During this when the spine flexes,the pelvic tilt and anteversion are reduced. Due to this movement maximum femoroacetabular flexion is achieved risking anterior impingement of the hip.

SPINOPELVIC PARAMETERS IN PATHOLOGICAL STATE(Figure-2)

In various pathologies of the hip such as arthritis there will be significant differences in the spinopelvic parameters. In these cases femoroacetabular flexion is reduced which leads to increased pelvic tilt while adopting a relaxed seated position and the overall sagittal arc is reduced[10].

SPINOPELVIC PARAMETERS IN POST TOTAL HIP ARTHROPLASTY(Figure-3)

Following total hip arthroplasty the spinopelvic hypermobility resolves while transitioning from standing to sitting position which could be due to restoration of hip flexion. [10,11,12]

In these cases the spine is no longer required to perform most of the actions and hence the lumbar spine flexion is reduced.

George Grammatopoulos et al suggested that there is no universal safe zone for Acetabular cup orientation. Patients with spinal arthrodesis or degenerative lumbar spine are at increased risk of dislocation and have narrower zone of optimal cup placement. The static spinopelvic parameters that are directly associated with increased risk of dislocation are lumbopelvic mismatch (pelvic incidence-lumbar lordosis angle>10 degree), high pelvic tilt (> 19 degree), and low sacral slope when standing. A High Combined Saggital index (CSI) when standing (>245 degree) is associated with increased risk of anterior instability, while low CSI when standing (<205 degree) is associated with increased risk of posterior instability.[13]

The functional cup orientation is a term commonly used in the literature and describes the patient specific, optimal cup orientation having considered individual anatomical factors as in theory the functional cup orientation would lead to superior function.[14]

Hip instability is multifactorial but a few studies have shown high prevalence of concomitant spinopelvic pathology and under restoration of hip offset which might have caused dislocation after Total hip arthroplasty.[15]

IMPLICATIONS FOR TOTAL HIP ARTHROPLASTY

According to Lewinnek, Arthroplasty surgeons use the long-established "safe zone" (cup anteversion 15 ± 10 degrees and inclination 40 ±10 degrees). [16]
The static position (supine or lateral during THA) does not take into account the functional changes caused by pelvis rotation when changing positions from standing to sitting. In general, a more functional position including pelvis rotation is considered in standing anteroposterior pelvis radiographs compared to supine radiographs; therefore, a standing anteroposterior pelvis reference radiograph is preferred [17,18].

The "functional acetabular cup position" introduced by Lazennec can be considered when performing THA as he was a pioneer in studying the complex interactions of hip and spine and their influence on total hip arthroplasty. [19] In recent years, increasing concerns were raised about the long established safe zone. Tezuka et al. found in their study that THA patients within the safe zone, but outside the functional safe zone based on the measurement of combined sagittal index, had a probably higher risk of dislocation despite "correct" angles regarding the safe zone [20].

Phan et al. defined four groups based on spinopelvic mobility (flexible or rigid) and sagittal spinal balance (balanced or unbalanced). For the flexible and balanced group, they recommend an acetabular anteversion of 5–25 degrees. The rigid and balanced group presents reduced acetabular anteversion due to a decreased posterior pelvic tilt while sitting. To avoid anterior impingement and posterior dislocation in a sitting position, anteversion at the superior end of the safe zone of 15–25 degrees should be aimed for. The flexible and unbalanced group shows increased acetabular anteversion due to increased posterior pelvic tilt during standing as compensation for spinal imbalance. There are two possible treatment pathways for the flexible and unbalanced and rigid and unbalanced spine patients.

The first option is performing spinal correction surgery before THA, leading to patients with balanced spine, and then aiming for the corresponding procedure for the rigid and balanced group. The second option, when prior spinal surgery is refused, is performing cup positioning with reduced anteversion to reduce the risk of posterior impingement in kyphotic patients when standing. The second option involves the risk that a THA revision procedure may be necessary if the patients undergo a surgical spinal realignment. [21]

Kanawade et al. defined three groups based on spinopelvic mobility. **For the patients with stiff pelvis [Anterior pelvic plane angle (APPt) < 20 degrees],** they recommend increased anteversion and inclination, and, for the patients with **hypermobile pelvis** (APPt > 35degrees), they recommend reduced anteversion and inclination, compared to patients with normal spinopelvic mobility (cup implantation anteversion 20 degrees and inclination 40 degrees). [22]

Stefl et al. [23] classified patients according to spinopelvic mobility into normal, hypermobile,stiff "stuck standing", stiff "stuck sitting", kyphotic, and fused. For hips with normal mobility, they suggest 40 degrees inclination and 20 degrees anteversion with a combined anteversion of 25 to 40 degrees.

According to Kanawade et al. [22] , a reduction of anteversion (35 to 40 degrees) and inclination (15 to 20) is recommended for hypermobile and hypermobile kyphotic hips to prevent the cup position being too vertical while sitting. For hips with limited mobility (**stiff, "stuck standing", or "stuck sitting")**, they recommend increasing the inclination (45 degrees) and anteversion (20 to 25 degrees), as well as combined anteversion (35 to 40 degrees), to achieve a functional opening of the acetabulum while sitting. Patients with a kyphotic lumbar spine (SS < 5 degrees) and normal mobility may receive standard anteversion and inclination. Special attention should be paid to patients with kyphotic lumbar spine and stiff pelvis. **These patients were identified to have a high risk of dislocation; therefore, the implantation of a dual-mobility articulation should be considered [23] .Hip surgeons are not only faced with the challenge of ensuring high implant stability; they also need to consider the range of cup orientations with regards to minimizing wear** [18] .

Luthringer et al. [17] classified patients into four groups depending on spinopelvic mobility and spinal alignment. For patients with **normal spinal alignment** (no Pelvic Incidence–Lumbar Lordosis mismatch) and **normal mobility** (Group 1a), the classical anteversion of 20–25 degrees is recommended. Group 1b shows limited mobility (<10 degrees SS from standing to sitting) and, thus, a reduced posterior pelvic tilt while sitting. Hence, these patients should be given increased anteversion (30 degrees) of the cup to avoid anterior impingement and subsequent posterior dislocation.

In Group 2a (**flatback deformity and normal mobility**), it should be noted that the spinal deformity leads to increased posterior pelvic tilt in a standing position and, thus, to increased acetabular anteversion.

Reference should be made to the anteroposterior pelvis standing image with an anteversion of 25–30 degrees. In Group 2b (**flatback deformity and stiff spine**), there is a narrow safe zone of recommended increased anteversion (30 degrees) to prevent anterior impingement while sitting without creating too much anteversion while standing, which carries the risk of posterior impingement. Thus, the authors recommend here, similar to Stefl et al., that the use of dual-mobility articulation be considered [17, 23] .

TABLE 3 Luthringer and Vigdorchik's treatment recommendations based on spinopelvic mobility and presence of fixed sagittal plane imbalance

Parameter	Balanced	Unbalanced
Normal mobility (A)	Acetabular component anteversion 20°-25° in APP=FPP planes	Acetabular component anteversion 25°-30° in FPP, which is not similar to APP
Stiff spine (B)	Acetabular anteversion 30° in APP≈FPP planes	Acetabular component anteversion 30° in FPP, which is not similar to APP

A stiff spine was defined as <10° change in SS from standing to sitting. Fixed sagittal plane imbalance was defined by PI-LL>10° when standing.
APP: anterior pelvic plane; FPP: functional pelvic plane; SS: sacral slope; PI: pelvic incidence; LL: lumbar lordosis

DISCUSSION

Despite the evolution of the total hip arthroplasty implants and the continuous efforts to improve the surgical techniques dislocations of THA is not uncommon[24] .In a view to decrease the rate of dislocation extensive studies have been made about the spinopelvic instability and there seems to be a strong correlation between the two.

Spinopelvic movement is potentially a complex issue and was long underestimated by hip arthroplasty surgeons. However, it is relevant due to the predicted increase in the incidence of patients with osteoarthritis and spinal pathologies and the subsequent increase in THA [25,26] .

Understanding the reasons for THA dislocations is an important step in their prevention. One of the reasons for dislocations is **restriction of spinopelvic mobility** or spinal imbalance, especially in late THA dislocations [27] .Consequently, arthroplasty surgeons should assess spinopelvic mobility and sagittal balance in their patients before THA. Preoperative X-ray evaluation should be considered,especially in patients with suspected limited spinopelvic mobility, such as history of lumbosacral fusion, kyphotic standing posture, severe spinal degenerative disease, hip flexion contractures, and history of THA dislocation and revision surgery.

Since it causes additional strains for patients and surgeons, comprehensive diagnostics should be contemplated at least for high-risk patients. **Arthroplasty surgeons often align the implant positioning with the static position in an anteroposterior pelvis supine radiograph.**

In order to reflect the dynamic interactions, the functional position of the pelvis should instead be considered using an anteroposterior pelvis standing radiograph. When evaluating THA candidates, spinal stiffness (SS < 10degrees [17] or SS < 20 degrees [22]) should be assessed by performing lateral X-rays of the spine from L1 or C7, including the pelvis and proximal femur, in sitting and standing positions. **Stiffness leads to limited posterior pelvic tilt (APPt) from standing to sitting with reduced acetabular anteversion and possible anterior impingement. Therefore, an increased anteversion cup positioning is recommended.**

Despite efforts to reduce the rate of dislocation by taking into account the spinopelvic parameters, it should be remembered that THA dislocations may have many causes such **as surgical approach, soft tissue damage, previous surgery, and malposition of the implants.** It should also be mentioned that acute postoperative dislocations are usually not due to abnormal spinopelvic mobility [28] .

CONCLUSION

There has been a dramatic decrease in dislocation rates of total hip arthroplasty due to technology, surgical technique and newer implant designs. The study of relationship of the pelvis, spine and femur will further help to decrease the dislocation rate. This will eventually help the surgeon to place the components in such a way that an impingement free range of motion can be achieved. In order to achieve that as well as decrease the rate of dislocation the surgeon can modify and use high offset femoral and acetabular liners, dual mobility articulations and constrained liners. Hence, implant positioning should be based more on functional rather than static aspects.

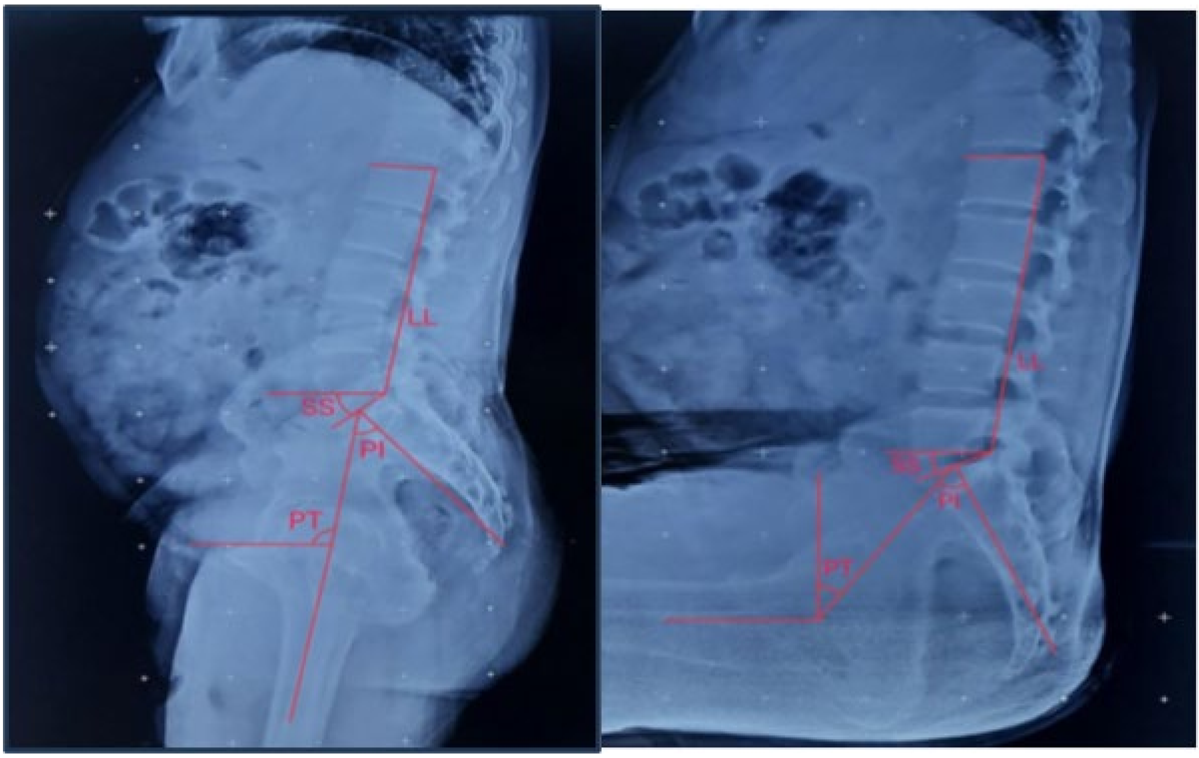


Figure 1: Spinopelvic measurements in a normal patient. Standing: PI: 51, PT:100, SS: 40.5. Sitting: PI:63, PT: 38, SS: 26

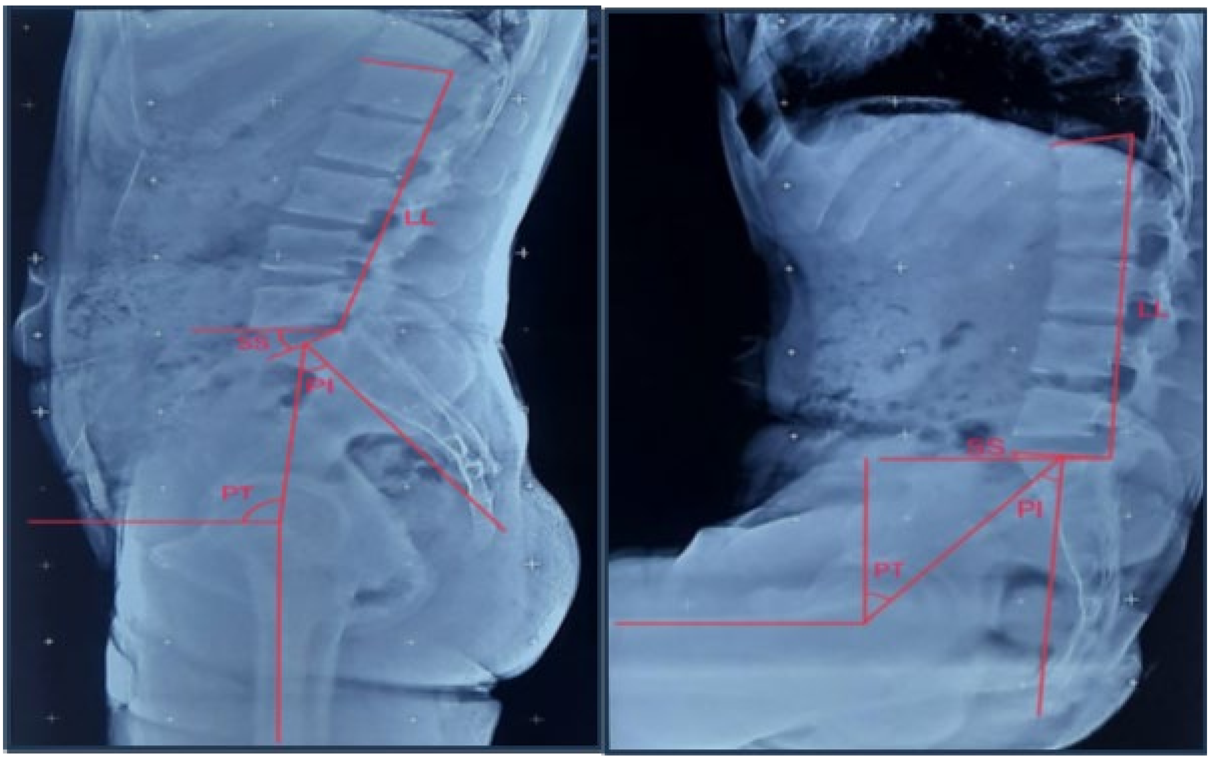


Figure 2: Spinopelvic measurements in a hip pathology. Standing: PI: 41, PT: 98, SS: 34
Sitting: PI: 41, PT: 42,

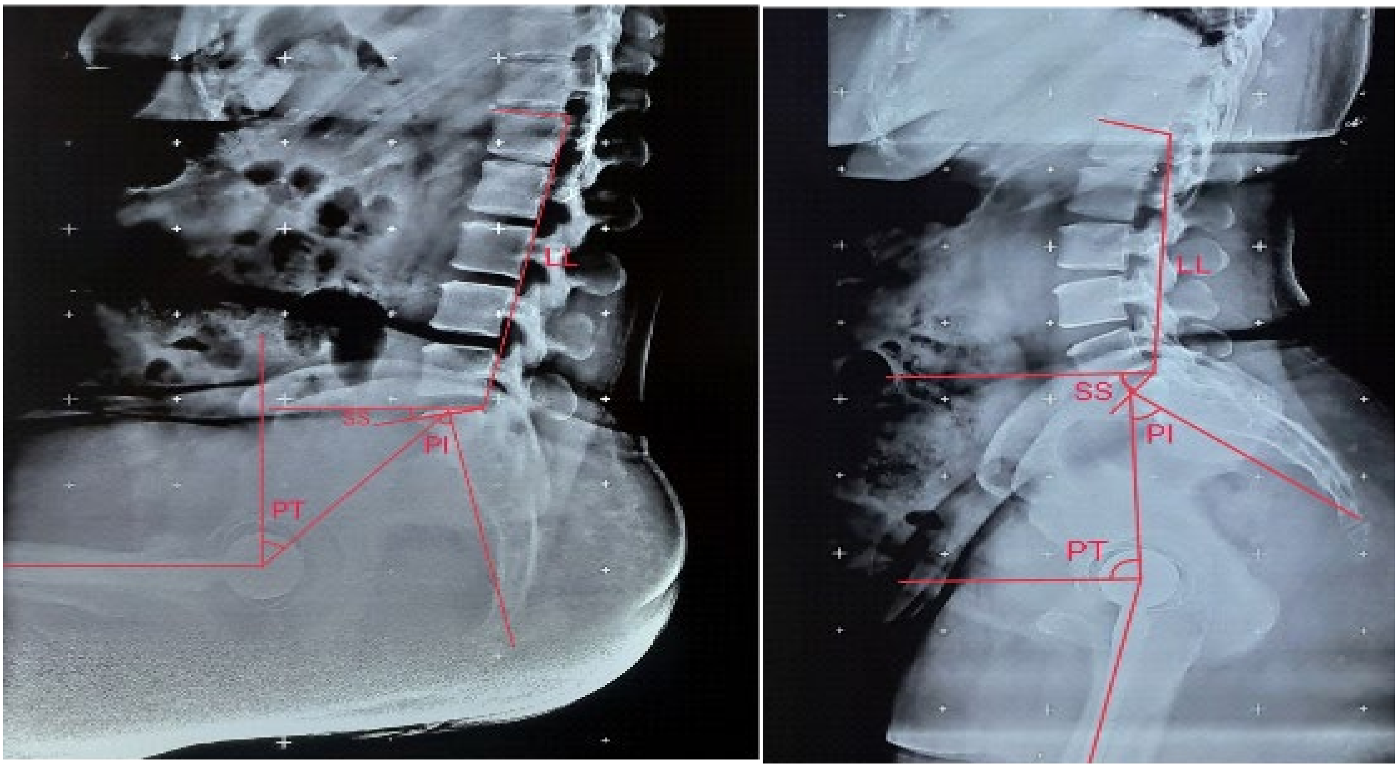
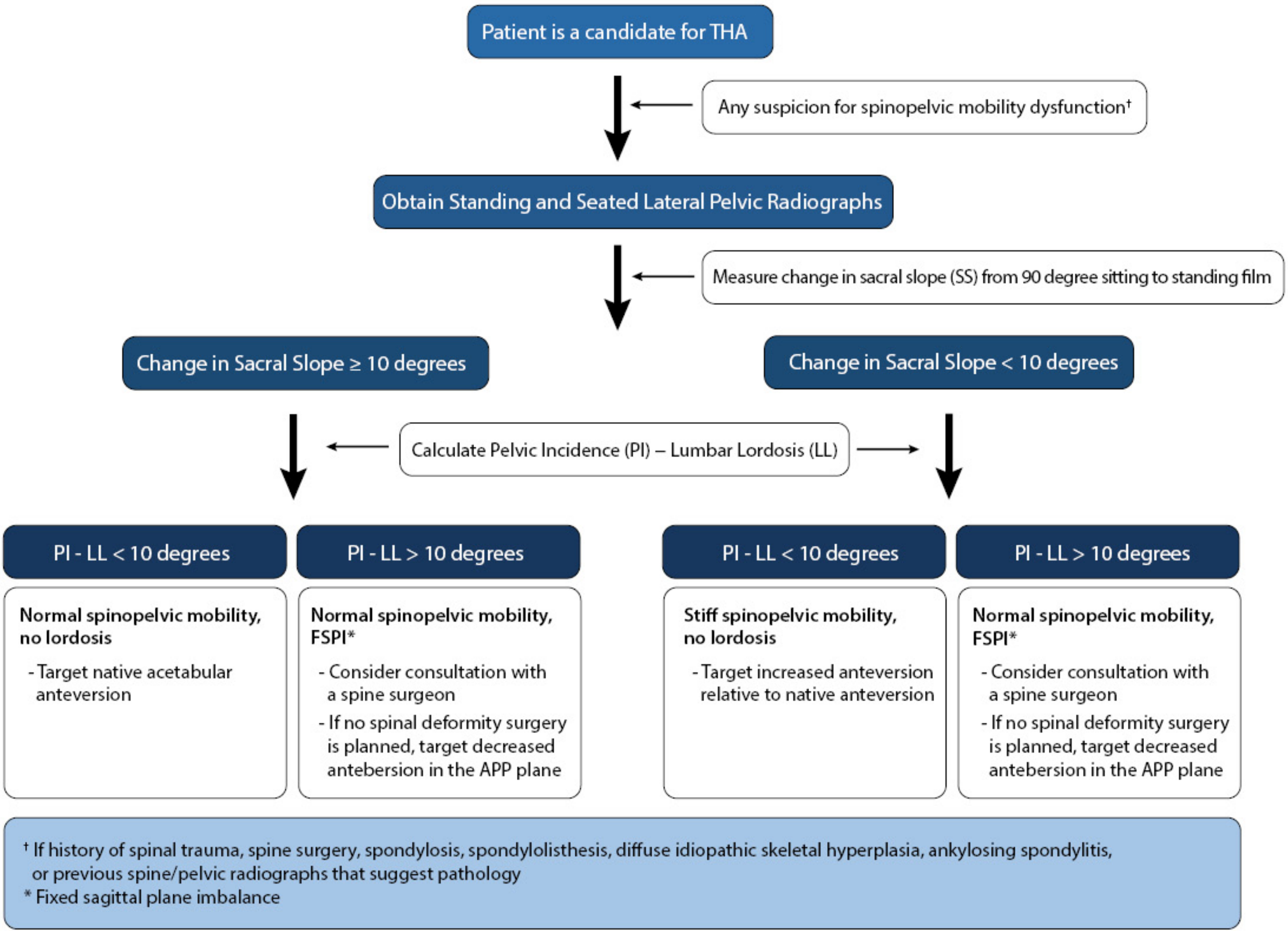
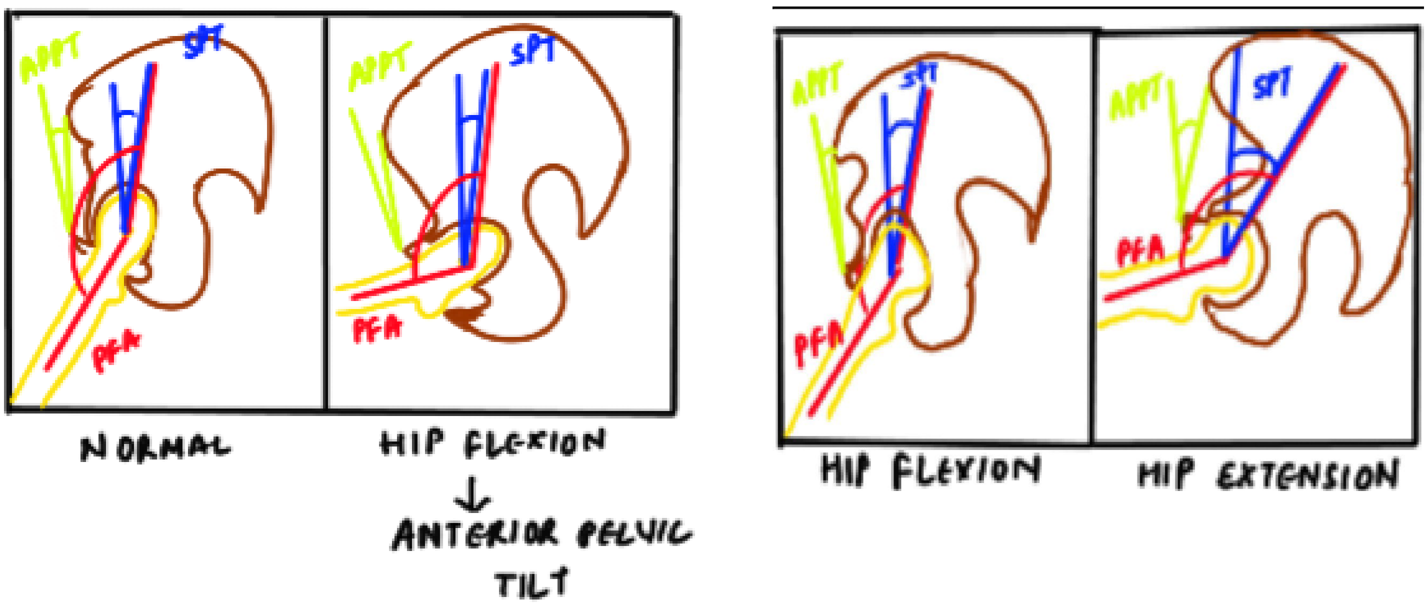


Figure 3: Spinopelvic measurements after Total Hip Arthroplasty.
Sitting: PI:57.5, PT:46, SS: 12.   Standing-PI: 53, PT:92, SS: 55 Degr



parameters---when hip and pelvis are both mobile due to flexible spine



parameters---when hip is mobile and pelvis is fixed

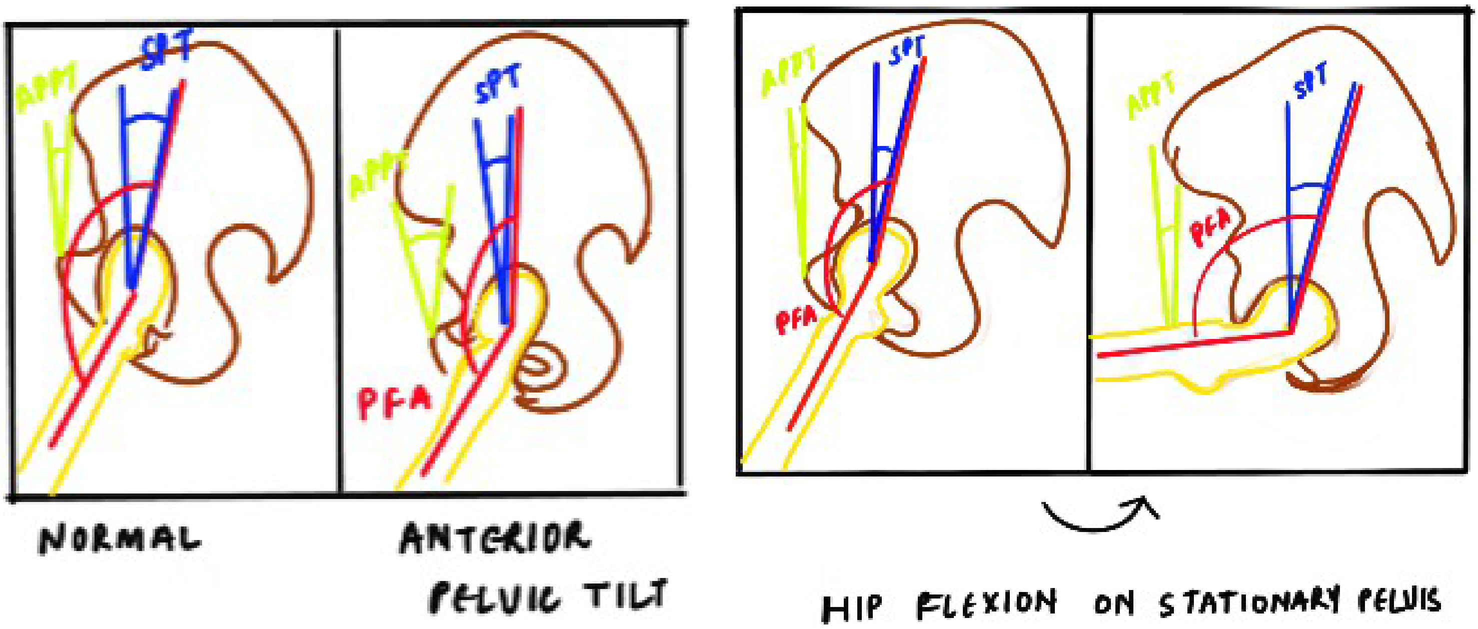


Figure 4: Spinopelvic parameter

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