IJOA

Indian Journal of Arthroplasty

Official Publication of The Indian Arthroplasty Association

Volume 1 Issue 1 July–September 2024

Indian Arthroplasty Association

Everything about Joints.

JAYPEE

www.jaypeejournals.com
www.ijoa.net

Indian Journal of Arthroplasty

1. Aims and Scope

Indian Journal of Arthroplasty (IJOA) is the official publication of the Indian Arthroplasty Association. The Journal publishes four issues in a year, i.e., January–March, April–June, July–September and October–December. It is a peer-reviewed, open-access Journal and aims to publish original research articles, controlled trials, review articles, case series and case reports and surgical techniques pertaining to joint replacement surgery only.

The publications should not have been published anywhere else either as an abstract or paper and should be the original work of the authors, free of any plagiarism. Original papers that may have an impact on the management outcomes after an intervention are welcome. Case series should be based upon the personal experience of the surgeon on a cohort of patients but should have originality and key learning message for the readers. Case reports should have a new or rare diagnosis or intervention that has been performed. Review articles should be on a topic that has clinical relevance and dictates the management guidelines.

Surgical techniques should have a strong anatomical basis and must have a clinical implication.

2. Ethical Considerations

Investigation and surgery on human subjects should conform to the guidelines noted in the World Health Organization Chronicle 1976;30:360–362.

Manuscripts submitted for publication must comply with the following ethical considerations:

Informed Consent

Informed consent of the patients must be taken before they are considered for participation in the study. Patient-identifying information, such as names, initials, hospital numbers, or photographs should not be included in the written descriptions. Patient consent should be obtained in written and archived with the authors.

Protection of Human Subjects and Animals in Research

When conducting experiments on human subjects, appropriate approval must have been obtained by the relevant ethics committees. All the procedures must be performed in accordance with the ethical standards of the responsible ethics committee (institutional and national) on human experimentation and the Helsinki Declaration of 1964 (as revised in 2008). When reporting experiments on animals, authors must follow the institutional and national guidelines for the care and use of laboratory animals.

3. Copyright

Following guidelines must be followed before submission of the manuscript:

The articles must have declaration in relation to original research or any other material that "article has not been published before and is not under consideration of publication elsewhere." This, however, does not include previous publication in form of an abstract or as part of published literature (review or thesis). It is the duty of the author to obtain the necessary permissions for extensive quotations, tables, illustrations or any other material they are using in the paper before a paper can be considered for publication. The authors retain the Copyright of the article. At the time of article submission, the author would be asked to sign the 'Open Access License Agreement Form' before their article is considered for publication. Once the author/authors have signed the Open Access License Agreement Form, no authorship change, or the authors' order listed on the article will be accepted by Jaypee Brothers Medical Publishers Pvt Ltd. However, if there is a genuine reason for authorship and authorship sequence changes, the authors should complete the "Authorship change request form" with a signed statement of agreement for the requested change from all listed authors and the author to be removed or added and send it to the Journal Editor-in-Chief (EIC) along with a letter explaining the reasons for the proposed changes; EIC will consider these requests on a case-to-case basis although not mandatory. Also by signing the above-mentioned form, the author reassigns the rights of copublishing or translation if considered necessary in future to the editor or Publisher. In the advent of occurrence of any dispute, the matter would be resolved within the jurisdiction of New Delhi court.

While all care will be taken to provide accurate and correct information in accordance with the date of publication, neither the authors/editors nor the Publisher takes any legal responsibility for any unintentional omission or error. The editors or Publisher makes no expressed or implied warranty with respect to the information contained herein. The published material cannot be photocopied for the following purposes: General distribution, promotion, new works or resale. If this is required, specific written permission must be obtained from the editor or Publisher. Exclusive rights to reproduce and distribute the articles in the Journal have been protected by copyright. This also covers the rights to reproduce or distribute the article as well as the translation rights. No material published in the Journal can be reproduced in digital format or stored in the forms of electronic databases, video disks, etc.

Both the conflict of interests and financial disclosure need to be handled well while conducting the research study. Disclosure of such relationships is also important in connection with all articles submitted for publication. Both of these have also been included in the Commercial Rights Transfer Form. Authors should give due acknowledgment to the individuals who provide writing or other assistance while conducting the research study and also disclose the funding source for the research study.

4. Subscription Information

• Subscription rates

For information on subscription rates and the other journal-related enquiries, please contact:
subscriptions@jaypeebrothers.com

• Orders

Journals Department
Jaypee Brothers Medical Publishers (P) Ltd.
4838/24, Ansari Road, Daryaganj
New Delhi 110 002, India
Phone: +91-11-4357 4357
Fax: +91-11-4357 4314
e-mail: subscriptions@jaypeebrothers.com

5. Electronic Media

An electronic edition of this journal is available at **www.jaypeejournals.com**
Manuscripts can be submitted online at **www.ijoa.net**

6. Advertisement

For advertisement queries, please contact:
Journals Department
Jaypee Brothers Medical Publishers (P) Ltd.
e-mail: sanjeev.kumar@jaypeebrothers.com

For any queries regarding online submission, please e-mail us at:
ajay.sharma@jaypeebrothers.com

For editorial queries, please contact:
editor@jaypeebrothers.com

The Journal is printed on acid-free paper.

Editorial Board

Editorial and Production Office
Journals Department
Jaypee Brothers Medical Publishers (P) Ltd.
4838/24, Ansari Road, Daryaganj
New Delhi-110 002, India
Phone: +91-11-43574357
Fax: +91-11-43574314
e-mail: editor@jaypeebrothers.com

Advertisements/ Subscriptions/ Reprints
Sanjeev Kumar
Phone: +91-9868850291
e-mail: subscriptions@jaypeebrothers.com
sanjeev.kumar@jaypeebrothers.com

For Website Queries
Phone: +91-11-43574357
e-mail: journals.editor@jaypeebrothers.com

Message from the President

10.5005/ijoa-1-1-iv

Dear esteemed members of the Indian Arthroplasty Association,

It is with immense pride and joy that I announce the launch of the very first issue of our Association's Journal. This milestone has been a long-standing need for our community, and I am thrilled to see it finally become a reality.

The journey to this moment has not been without its challenges. Many members have contributed over the years, laying the groundwork for this achievement. Our core committee's recent efforts have been instrumental in overcoming initial hurdles and bringing this vision to life.

As we celebrate this accomplishment, we recognize that our work is far from over. Our commitment to publishing four issues annually demands unwavering dedication and perseverance. Our ultimate goal is to achieve indexation within the next two years, solidifying our Journal's reputation as a premier platform for arthroplasty research and knowledge sharing.

To achieve this ambitious objective, I invite each of you to join forces and contribute to the Journal's success. Your active participation will be instrumental in sustaining this endeavor. I encourage you to share your expertise through case reports showcasing unique challenges and solutions, tips and tricks gleaned from your experience, innovative techniques and approaches besides your original research and review articles.

Your contributions will not only enrich our Journal but also enhance our collective understanding of arthroplasty. By sharing your knowledge, you will advance the field through evidence-based practices, inspire colleagues and shape the next generation of arthroplasty specialists.

Our aim is to foster collaboration and networking within our community and elevate the Indian Arthroplasty Association's reputation globally.

I extend my gratitude to past leaders and members who laid the foundation, our core committee for their relentless efforts and the editorial team for their tireless work.

A special note of appreciation of the efforts of our Past President Dr Anoop Jhurani who did the initial spadework and to Dr Mrinal Sharma for taking the mantle of editorship and ensuring that this Journal sees the light of day.

As we embark on this exciting journey, I seek the unwavering support of our members to patronize the Journal by contributing manuscripts regularly, participate in peer review and most importantly provide feedback and suggestions.

Together, let us create a world-class Journal that reflects our Association's excellence and dedication to advancing arthroplasty care.

Thank you for your commitment to our shared mission.

Sincerely,

Dr M Ajith Kumar
President, Indian Arthroplasty Association

10.5005/ijoa-1-1-v

Message from the Secretary

It gives me immense pleasure to be a part of this great initiative as a Secretary of the Indian Arthroplasty Association to bring out a Journal of its own as there is a need for the subspecialty research in the field of orthopedics. In recent decades, many advancements have happened in arthroplasty but the interest in research is not growing in accordance and in that context when there is opportunity for everyone to publish, that will encourage all to take up research and innovations. The Journal from the Indian Arthroplasty Association will help the surgeons to learn the nuances of doing research and also the art of writing a good article. This also provides a platform for Indian surgeons to showcase their work globally. Our aim is to get this Journal indexed as early as possible, which is the main focus. We are working to ensure a fair and prompt process of review of the articles for the authors and give the readers a regular issue without any delay. Arthroplasty specialty itself is growing in leaps and bounds but that needs to be fine-tuned with good research and for this I feel our Journal is the need of the hour.

The entire team in the Journal committee has put in a lot of efforts to get the first issue released in our upcoming annual conference. I would request all the readers of this inaugural issue to spread the information about the Journal from the Indian Arthroplasty Association so that more and more good articles are sent regularly. Once again, I am taking this opportunity to congratulate the Indian Arthroplasty Association for venturing in to bring out a Journal of its own.

Wishing you all the best!

Dr Rajkumar Natesan
Secretary, Indian Arthroplasty Association

EDITORIAL

10.5005/ijoa-1-1-vi

Indian Journal of Arthroplasty: The Beginning of a New Era

Arthroplasty practice and outcomes vary from region to region and across continents. The varied demands and presentations of patients from around the world influence best practices in arthroplasty. The grotesque deformities and the posttraumatic presentations seen in the Indian scenario are far more complex with relatively inferior outcomes. The implant choice may be different for different physiques, phenotypes, and races. Similarly, the postoperative regimen followed, and the thromboprophylaxis given may vary from country and region. Even the kind of periprosthetic joint infection and the bugs isolated may vary among regions and races. Almost all of the diagnostic criteria, prophylaxis and management protocols are based upon data generated from the studies conducted in the West and the published Western literature. These might not be fully applicable to the Indian and Asian populations.

With an aim to encourage research at the ground-root level in the Indian arthroplasty scenario and to generate data on Indian subjects, so that diagnostic criteria and management protocols can be established, the *Indian Journal of Arthroplasty* was conceptualized. This Journal was the dream of the many past leaders of the Indian Arthroplasty Association, but it was the brainchild of Dr Anoop Jhurani, who took pains in getting the ball rolling. Under the leadership of our present President Dr Ajith Kumar, the Journal would see the light of the day. The fact that it is being published under the aegis of the Indian Arthroplasty Association, itself carries a lot of weight and we hope to carry the baton forward. I am deeply honored by the confidence shown by the core committee and shouldering upon me the responsibility of being the Editor-in-Chief of the Indian Journal of Arthroplasty.

We aim to publish concise, authoritative, and scholarly articles in our Journal that would impact the current practice of Arthroplasty. The Journal aims to publish four issues in a year. The *Indian Journal of Arthroplasty* would accept articles on joint replacement surgery of knee, hip, ankle, shoulder, elbow, and wrist. We encourage invited editorials on topics of interest to a larger readership. Original research articles in Arthroplasty should have a deep impact of the current practices in the Indian scenario. All the articles would be submitted online and undergo a peer review process before final publication. We would also accept case series that would highlight and discuss the surgeon's experience on that particular issue. The Journal would also accept unique case reports and newer surgical techniques. The review articles/meta-analysis would provide insight into the current practices related to a particular topic in Arthroplasty and lay a guideline for future practices.

In the long run, we aim to publish data outcomes from the Indian Joint Registry and take out white papers that would dictate the Arthroplasty outcomes.

With pride and honor, we present to you the *Indian Journal of Arthroplasty* which would usher India into a new era of research in Arthroplasty.

Regards

Mrinal Sharma
Editor-in-Chief
Indian Journal of Arthroplasty

IJOA
Indian Journal of Arthroplasty
Official Publication of The Indian Arthroplasty Association

Volume 1 **Issue 1** **July–September 2024**

Contents

Research Articles

Comparative Long-term Outcomes of All-polyethylene vs Metal-backed Tibial Components in Total Knee Replacement: An Indian Perspective 1
Ravikumar Mukartihal, Manideep Reddy R, Mithun Manohar, Harsha J, Shrishti S Patil, Sharan S Patil

A Simple Subjective Surgical Complexity Score for Surgical Planning in Total Knee Arthroplasty Helps to Improve Surgical Efficiency and Reduce Costs 7
Amar S Vadhera, Joseph Koressel, Cynthia E Law, Matthew Stein, Neil P Sheth

Navigation-assisted vs Non-navigation-assisted Total Knee Replacement in Obese Patients: A Comparative Randomized Study 13
Mrinal Sharma, Muntashir Ashraf PK

Significance of Grand Piano Sign for Rotational Alignment of Distal Femur during Total Knee Arthroplasty 21
Manish Shah, Dharan Shah, Ishani Patel, Mansi Patel, Neel Bhavsar, Dhaval Modi, M Ajith Kumar

Review Article

Augmented Reality in Total Knee Replacement (TKR): A Narrative Review 25
Amit K Yadav, Aatif Mahmood, Nikhil Shah

Case Series

Late Spontaneous Dissociation of Bipolar Hemiarthroplasty Components: A Case Series and Review of Literature 29
Amrit Goyal, Yashvardhan Sharma, Mayur Gupta, Ankit Kapoor, Jawahar Panjwani, Kartik Pruthi

Case Reports

Bilateral Knee Arthroplasty in Acromegalic Arthropathy: A Rare Case Report and Literature Review 37
Plaban N Chowdhury, Abhishek Vaish, Raju Vaishya

Bilateral Fused Hips with Stiff Spine in Ankylosing Spondylitis with Subtrochanteric Fracture Right Hip 43
Anil Thomas Oommen, Augustine Jaison Paul, Christo Jeyaraj, Ramu Viswarajan V

SUBSCRIPTION INFORMATION

Annual Subscription:

Individual:	₹	7,000.00	(National)
	$	350.00	(International)
Institutional:	₹	9,500.00	(National)
	$	400.00	(International)

Single Issue:

Individual:	₹	2,000.00	(National)
	$	100.00	(International)
Institutional:	₹	2,500.00	(National)
	$	150.00	(International)

Subscription can be sent to:
Journals Department
M/s Jaypee Brothers Medical Publishers (P) Ltd.
4838/24 Ansari Road, Daryaganj
New Delhi 110 002, India
Phone: +91-11-43574357
Fax: +91-11-43574314
e-mail: subscriptions@jaypeebrothers.com

This journal is published four times in a year, i.e., January, April, July and October. Dollar rates apply to subscribers in all the countries except India where INR price is applicable. All subscriptions are payable in advance and all the rates include postage. Journals are sent by air to all the countries except Indian subcontinent. Subscriptions are on an annual basis, i.e. from January to December. Payment will be made by Dollar cheque, credit card or directly through our bank account at the following address:

1.	Our Banker's Name:	ICICI Bank LTD.
2.	Our Current A/c No:	**JAYBRZ**
3.	Amount to be Transferred in the Name of:	JAYPEE BROTHERS MEDICAL PUBLISHERS (P) LTD., NEW DELHI
4.	IFSC Code:	ICIC0000106

For further queries, please do not hesitate to contact at subscriptions@jaypeebrothers.com

ADVERTISEMENT RATES

(For the Print Issues)

Page	Single Issue	
Back cover—color	₹ 50,000	$ 1000.00
Inside front cover—color	₹ 40,000	$ 800.00
Inside back cover—color	₹ 35,000	$ 700.00
Inside full page—color	₹ 30,000	$ 600.00

Special position: **Price on request**

Technical Details

Paper size	8.5" × 11"
Text size	7.5" × 10"
Digital file format	EPS on CD (at 300 dpi resolution)

Printed on art paper using offset printing.

Schedule

Issues are published in the months of January, April, July and October.
Advertisement material along with purchase order and payment should reach us at least four weeks prior to the scheduled print date.

Payment Details

- Payment should be in favor of 'Jaypee Brothers Medical Publishers (P) Ltd.' and should be payable at New Delhi, India.
- Payment to be done at the time of submitting the advertisement material/booking the advertisement. Please send your advertisement request, payment and advertisement material to the address given above. Editorial board reserves the right to accept or decline the advertisement.
  For further queries, please contact: sanjeev.kumar@jaypeebrothers.com

RESEARCH ARTICLE

Comparative Long-term Outcomes of All-polyethylene vs Metal-backed Tibial Components in Total Knee Replacement: An Indian Perspective

Ravikumar Mukartihal[1], Manideep Reddy R[2], Mithun Manohar[3], Harsha J[4], Shrishti S Patil[5], Sharan S Patil[6]

Received on: 14 July 2024; *Accepted on:* 10 August 2024; *Published on:* 01 October 2024

Abstract

Introduction: A total knee replacement is a surgical procedure to treat severe arthritis in the knee joint. The cruciate-sacrificing prosthetic design is one of the most frequently used in total knee replacement (TKR). There has been debate regarding whether metal-backed tibia (MB) or all-polyethylene (AP) tibial components are better for implants in terms of lifespan, clinical results, and complication rates. The big role played by selecting appropriate knee joint implants for osteoarthritis in developing countries is with economic constraints. Metal and all-polyethylene monoblock essentially can serve this purpose in knees without defects in bones that do not require modularity like stem extensions or augments. The aim of this study was to compare the long-term clinical and radiological results of metal-backed vs all-polyethylene cruciate-sacrificing total knee replacements. Long-term application of all-polyethylene tibial implants against the backdrop of better-designed implants/instrumentation coupled with an increasing use of TKR and continuous economic pressures on health care could represent a potential for enormous cost savings without jeopardizing patient clinical outcomes.

Materials and methods: This prospective study involves 200 TKR procedures using Depuy PFC AP implants and MB implants 100 in each group, conducted between January 2011 and January 2012, with 12-years follow-up. Patients age > 50 years with a definite diagnosis of osteoarthritis, severe knee pain or dysfunction disabling normal work and life, ineffectiveness of conservative treatment, and TKRs that did not necessitate bone grafting, modular stems or augments, or more constrained designs were included. Functional outcomes were assessed using the Knee Society Score (KSS), Western Ontario and McMaster University Osteoarthritis Index (WOMAC), and range of motion (ROM). Radiological assessments were performed to check for signs of loosening and malalignment. Implant survival was measured by revision surgery rates.

Results: The study cohort included 130 females and 70 males, with an average age of 61.3 years. Both the MB and AP groups showed significant improvement in KSS, WOMAC, and ROM over 12-years, with no statistically significant difference between the two groups. The implant survival rate was 96% for AP and 94% for MB. Aseptic loosening occurred in 2 AP and 3 MB cases, with polyethylene wear observed in the MB group due to micromotion, while the AP group showed only minimal poly wear.

Conclusion: The long-term outcomes of both AP and MB tibial components in TKR show comparable clinical and radiological success, with both designs significantly improving pain relief and functional outcomes in patients with severe knee arthritis. AP implants, in particular, demonstrated similar functional improvements and radiological stability, while offering the added benefit of reduced polyethylene wear. Given the lower cost of AP components, they represent a cost-effective solution in resource-limited settings without sacrificing patient outcomes.

Keywords: All-polyethylene, Metal-back tibia, Total knee replacement.

Indian Journal of Arthroplasty (2024): 10.5005/ijoa-11025-0001

Introduction

Total knee replacement (TKR) remains a gold standard in the management of end-stage arthritis, providing significant pain relief and improved function for patients with severely degenerated knee joints. Results at long-term follow-up are very good, with 95–99% survival rates at 15 years.[1,2] This highlights the efficacy and sustainability of this procedure.

In TKR, two types of tibial components exist: all-polyethylene (AP) and monoblock/modular metal-backed (MB). Each design has features that make it applicable and function in different ways. The first designs of the initial condylar knee by Freeman, Swanson, and Insall were all AP components.[1–3] Since the introduction of ultra-high-molecular-weight polyethylene in 1963, polyethylene has been a component of every type of TKR. Early studies demonstrated that the failure rates for AP tibia components reached as high as 27% at an average follow-up of 54.4 months, although this series had mediocre 10-year survival rates of only 68%.[4–6] This result was attributed to several factors: the primitive surgical techniques employed; poor implant fixation due to the use of first-generation cement; and the original AP tibia components had a flawed design of the keel, resulting in poor metaphyseal fixation. The clinical outcomes with AP tibia components have been on par with or even superior to those achieved with MBT components.[7,8] The MB tibia is designed with a metal base plate to enhance heat sink capacity and load transmission.[9,10] The modularity of the design and

[1–6]Department of Orthopaedics, Sparsh Group of Hospitals, Infantry Road, Bengaluru, India

Corresponding Author: Ravikumar Mukartihal, Department of Orthopaedics, Sparsh Group of Hospitals, Infantry Road, Bengaluru, India, Phone: +91 9880082479, e-mail: doctorcmravi@gmail.com

How to cite this article: Mukartihal R, Reddy MR, Manohar M, *et al*. Comparative Long-term Outcomes of All-polyethylene vs Metal-backed Tibial Components in Total Knee Replacement: An Indian Perspective. Indian J Arthroplasty 2024;1(1):1–6.

Source of support: Nil

Conflict of interest: None

intraoperative flexibility provided by such a design can substantiate stem extensions when needed. These attributes could be very useful in some cases with additional stability and customization. The cost, however, increases with MB content, which, in cases of uneventful surgery without large bone defects, may not provide any additional benefits. There are, therefore, questions regarding their cost-effectiveness, more so in resource-poor settings and the economic constraints on patients.

Conversely, the all-poly tibial component is inexpensive and has a monoblock of polyethylene, which makes it less complex in design. Although the all-poly does not have the modularity and adaptability of MB components, they have shown equivalent results in many clinical trials.

However, in practice, due to the unanimous opinion from earlier studies, the selection between AP and MB mostly depends on economics, particularly in developing countries. With an improved nocturnal understanding of TKR mechanics and the introduction of mechanical instrumentation, AP tibia component design has become biomechanically sound. The surgical technique has likewise improved, and modern AP tibia components perform and, if not superior to, MBT designs.[8–10] In addition to equivalent implant survivorship in several patient populations, modern AP tibia implants have some unique advantages.

Economic constraints play a vital role in medical decisions in India. What could prove to be a deterrent for many patients is the high-cost MB component, which suddenly brings in sharper focus on the probable advantages of more affordable AP components. In view of these findings, comparative studies regarding the long-term results of the AP and MB tibial components are urgently required in the Indian setup. This study will serve as a guideline for clinical practice and will guide patients toward the most appropriate and cost-effective care. Although a substantial body of literature exists on TKR outcomes worldwide, a paucity of literature on the performance of these implants within the Indian population persists specifically concerning their long-term functional outcomes and economic viability.

The results at long-term follow-up of AP and MB cruciate-sacrificing TKR regarding clinical, radiological, and functional outcomes and complications, along with the survival rate, in Indian patients are an attempt to provide evidence-based inputs that assist in making clinical decisions and enrich patient care in resource-limited settings.

Methods

In this prospective study, which was conducted between January 2011 and 2012 and was followed up until December 2023, 100 TKRs using Depuy PFC PS all-poly (AP) tibial implants and the first 100 TKRs using Depuy PFC PS metal-backed (CoCr) implants were performed. All patients in the two groups had to satisfy the following criteria: age > 50 years with a definite diagnosis of non-infected arthritis, severe knee pain or dysfunction disabling normal work and life, ineffectiveness of conservative treatment, and TKRs that did not necessitate bone grafting, modular stems or augments, or more constrained designs.

Following the preanesthetic evaluation and surgical fitness, the patient had undergone TKR. The patients were not randomized, but both components were purposefully used so that a comparative review such as this could be performed. The choice between all-poly and MB implants was based on the financial constraints of patients. The standard TKR used at our institution was applied in all cases. A midline longitudinal skin incision and medial parapatellar approach were used. Mechanical alignment was achieved using

Table 1: Demographic data of patients

	All-poly (n = 100)	*Metal-backed (n = 100)*	*p-value*
Average age at the time of surgery	61.9 ± 5.1	60.8 ± 4.2	0.087
Median age	61	61	
Sex			
Male	39	31	
Female	61	69	
Operated side			
Right	38	28	
Left	34	22	
Bilateral	28	50	

the Depuy PFC instruments. Bone cement was applied to the cut surfaces of the tibia and femur, as well as to the implant itself. Patellar denervation with electrocautery and osteophyte removal was performed in all cases.

Patients were initially followed up at 1, 3, and 6 months and then annually till 12-years for clinical and radiological assessments. Functional evaluations were conducted using the Knee Society Score (KSS), Western Ontario and McMaster University-Osteoarthritis Index (WOMAC), and range of motion (ROM). Radiological assessments involved standard knee X-rays to check for signs of loosening, collapse, and alignment. Revision surgery was considered the endpoint of implant survival.

Statistical Analysis

Data entry was done using MS Excel and statistical analysis was conducted using the SPSS 10.0 software. For parametric data, the unpaired Student's *t*-test was utilized, while the Mann–Whitney *U* test was employed for non-parametric data. Fisher's exact test was applied to compare discrete variables between the two groups. The Kaplan-Meier survival analysis with the log-rank test was used to compare survival rates. A *P*-value of < 0.05 was considered statistically significant.

Results

There were 130 (65%) female and 70 (35%) male patients in the total cohort. Thirty-nine males, 61 females in all-poly groups, whereas 31 males and 69 females in MB group. The average age at the time of implantation was 61.3 years, with a median age of 61 years; the average ages of patients treated with AP and MB were 61.9 ± 5.1 and 60.8 ± 4.2 years, respectively ($p = 0.087$), with the youngest patient being 52 years old and the oldest being 80 years. Demographic details are given in Table 1.

Out of 100 patients in each cohort, 7 in the AP group and 9 in the MB group were lost to follow-up due to unreachability or death (Table 2).

The follow-up duration was 12-years. The KSS for clinical and functional assessments showed significant improvements in both groups. For the all-poly implants, the KSS improved from 38.8 ± 5.2 to 85.3 ± 4.2 at the final follow-up, representing an average improvement of 46.5 ± 6.09 ($p = 0.22$). Similarly, there was no statistically significant improvement in KSS scores for the MB (CoCr) implants, with scores increasing from 38.03 ± 3.6 to 85.9 ± 3.2, resulting in an overall improvement of 47.9 ± 4.9 ($p = 0.24$).

The WOMAC scores also showed marked improvements. For the MB TKR group, WOMAC scores improved from 82.42 ± 5.1 to 16.35 ± 1.72, with an average improvement of 66.07 ± 5.29 ($p = 0.85$). In the all-poly TKR group, WOMAC scores improved from 82.3 ± 3.6 to 16.26 ± 1.9, with an average improvement of 66.04 ± 4.28 ($p = 0.72$).

The mean ROM was also significantly improved. In the MB TKA group, ROM increased from 97.8 ± 9.8 to 113 ± 5.9 degrees. Similarly, in the all-poly TKA group, ROM improved from 98.6 ± 9.8 to 113.9 ± 5.84 degrees ($p = 0.28$) (Table 3).

Intraoperative (Fig. 1) and radiological outcomes (Fig. 2) of all-poly tibia and MB tibia of patients at 12-years follow-up, without osteolysis, loosening, and good alignment without collapse.

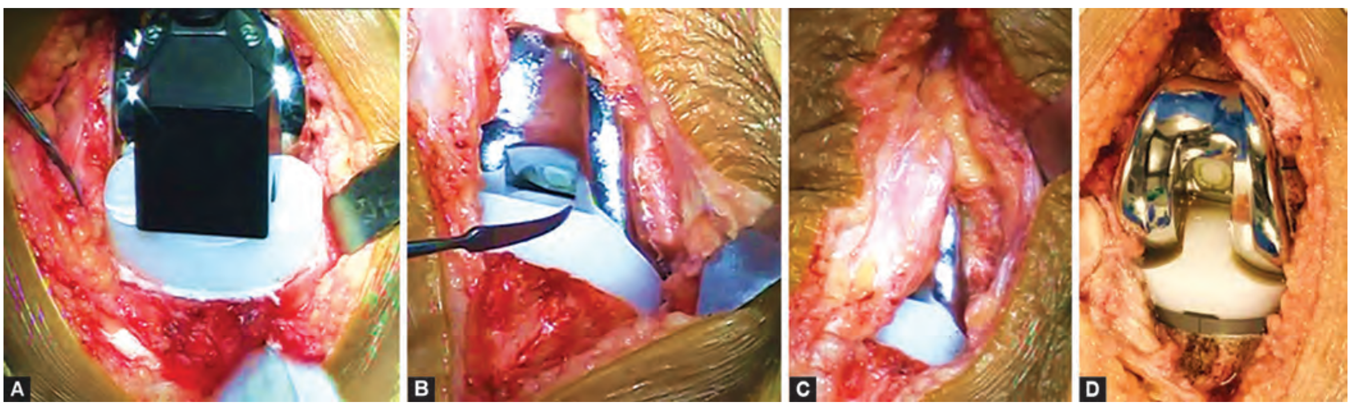
Table 2: Implant type, follow-up

	All-poly (n = 100)	*Metal-backed (n = 100)*
Implant type	Depuy all-poly tibia	Depuy MB tibia (CoCr)
Follow-up period	2012–2023	2012–2023
Follow-up duration	12-years	12-years
Lost to follow-up	4	5
Death	3	4

Two patients in the all-poly group and three patients in the MB group developed superficial surgical site infections, which were effectively treated with regular dressings and antibiotics, which were resolved. Additionally, two patients in the MB group and one patient in the all-poly group developed deep infections

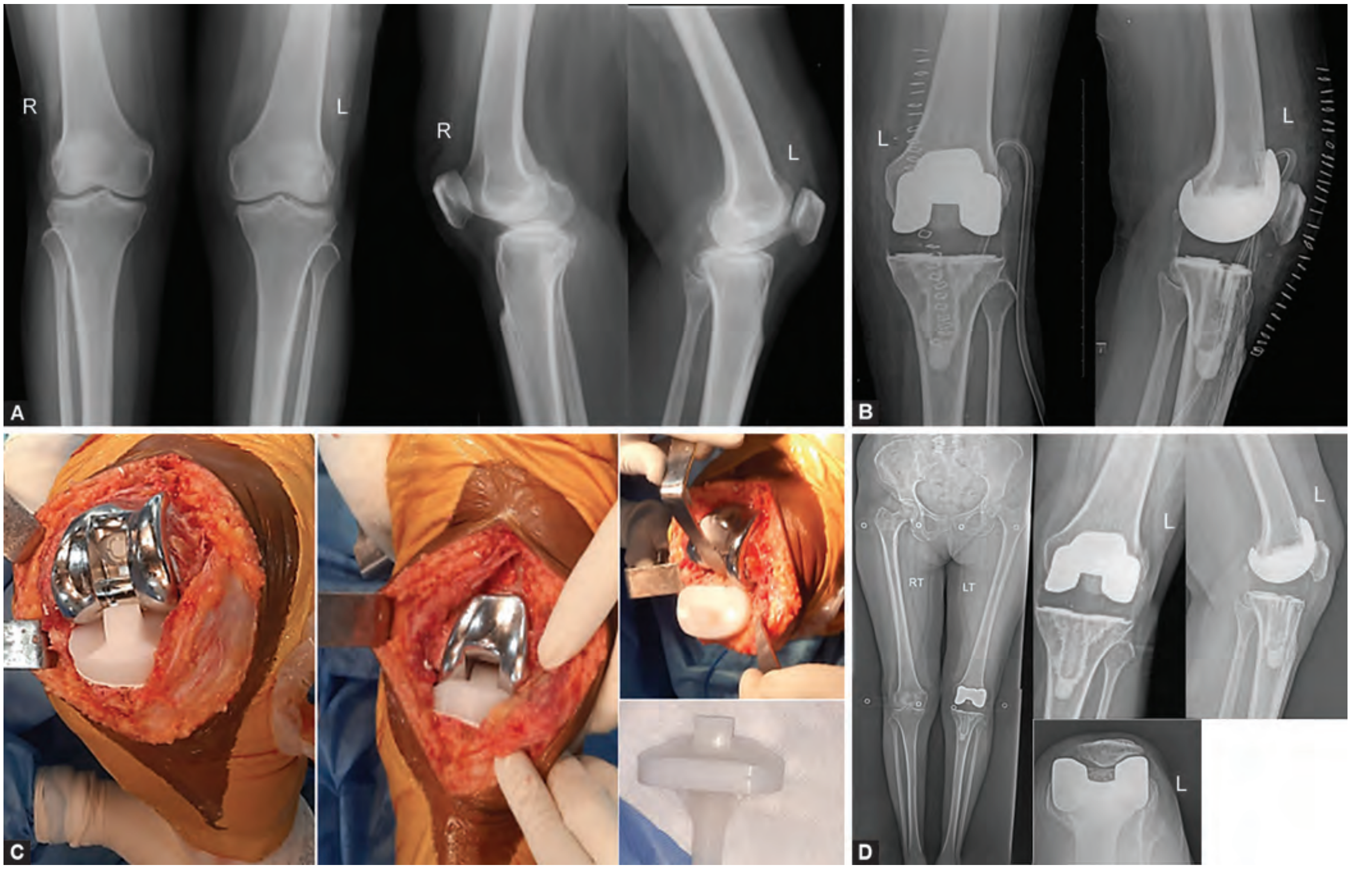
Table 3: Results of functional assessment

	All-poly (n = 100)	*MB (n = 100)*	*p-value*
KSS Preop	38.8 ± 5.2	38.03 ± 3.6	0.22
KSS at final follow-up	85.3 ± 4.2	85.9 ± 3.2	0.24
Change in KSS	46.5 ± 6.09	47.9 ± 4.9	
WOMAC Preop	82.3 ± 3.6	82.42 ± 5.1	0.85
WOMAC at final follow-up	16.26 ± 1.9	16.35 ± 1.72	0.72
Change in WOMAC	66.04 ± 4.28	66.07 ± 5.29	
Pre-op ROM (Degrees)	98.6 ± 9.8	97.8 ± 9.8	0.56
ROM at final follow-up	113.9 ± 5.84	113 ± 5.9	0.28



Figs 1A to D: Intraoperative pictures (A to C) All-polyethylene tibia; (D) Modular metal-backed tibia

Figs 2A and B: 12-year follow-up X-ray of (A) all-poly tibia (AP) TKR and (B) metal-back (MB) tibia TKR



Figs 3A to D: A case of all-poly tibia at 12-year follow-up

at an average of 2.5 years after the initial surgery, necessitating revision procedures. One patient in the all-poly group sustained a periprosthetic fracture due to trauma, which required revision TKA using a hinged prosthesis. Furthermore, two patients from the all-poly group and three from the MB group underwent revision TKA at an average of > 5 years from index surgery due to backside polyethylene wear leading to aseptic loosening.

In cases of aseptic loosening, the retrieved components—two from the AP group and three from the MB group—were examined for wear on the backside and articulation side. Polyethylene deformation was seen in the MB group due to undersurface micromotion between the insert and the tibial tray. On the other hand, there were no alterations to the polyethylene undersurface in the AP tibia group and only a slight delamination at the articular surface.

The overall survival rate of implants in our study was 96% in AP groups (Fig. 3) and 94 % in MB tibia group. Figure 4 shows Kaplan–Meier survivorship of AP and MB tibia.

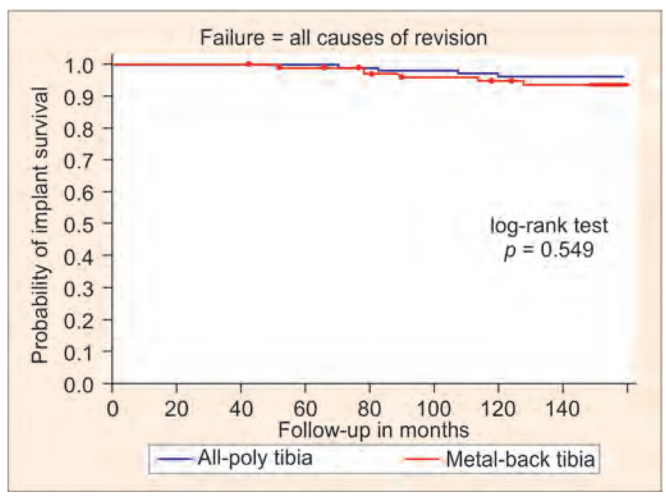


Fig. 4: Kaplan–Meier survivor curves of AP and MB tibia group

Discussion

The rates of total joint replacement are increasing significantly.[1–3] The initial design of TKR utilized an AP tibial component. Due to the subpar design of these components and the inferior quality of the polyethylene material available at that time, the survival rate for this type of prosthesis was reported to be as low as 68.11% after approximately ten years.[4,5] In modern orthopedics, MB tibial TKR is generally preferred over AP tibial implantation. According to arthroplasty registries, only 0.1% of TKRs use AP tibia.[6, 11] Given that AP tibia components are significantly cheaper than their MB counterparts, regardless of the manufacturer, more frequent use of all-poly monoblock could result in substantial cost savings for the health care system.

When metal backing was first introduced, it was thought to extend the survival of the tibial component longer than AP implants. Apel et al.[12] and Rand et al.[13] conducted studies comparing non-modular MB implants vs AP implants during an 8–10-year follow-up period. The study's findings showed no discernible differences between the two. Modular MB implants have been the subject of several other investigations, some of which have found exceptional survivability and durability.[14–19]

The use of AP tibial components decreased in the 1980s because of the excellent results of MB tibial components. As a result, MB components have come to the forefront of implantation in TKR. The advantages of MB tibial components are that the facility is available for changing the poly after the trial prosthesis has been inserted, during revisions or infections. They provide a good prosthesis-to-bone contact interface with additional modular augments or stems for lost bone. MB components are believed to offer the advantage of enhanced load distribution to the proximal tibia, as demonstrated by *in vitro* biomechanical studies.[15]

Despite these advantages, MB components have some disadvantages. These include decreased thickness of polyethylene, which may result in increased wear, and it is necessary to resect more tibia to accommodate a thicker insert.[16] The construct with MB components was stiffer and thus increased the stress on the tibia at the interface due to eccentric loading *in vitro*. Wear on the backside remains a major concern due to its modularity. The investigation conducted by Engh et al.[17] revealed a higher occurrence of osteolysis in tibial components with modular metal backing. Analysis of revised liners revealed significant damage and wear on the non-articular surface of the polyethylene, which is regarded as the primary source of polyethylene debris. This debris is a leading factor contributing to aseptic loosening in the modular MB group.[18–20] Which was a similar finding in our study in all revised cases. These complications, added to their higher cost, make MB components less advisable for cases that do not require modularity.

Modern highly cross-linked polyethylene is more resistant to wear, oxidation, and pressed and has more congruent articulation. Recent studies have shown that AP components are equal to or even superior to MB components. Adalberth et al.[21] reviewed 40 MB and AP components with no evidence of complications due to fixation; there were no bony collapse, no increased subsidence, and no increased incidence of radiolucent lines when comparing the AP group to the MB group. Norgren et al.[22] evaluated 21 patients in whom AP components showed magnitudes of migration on par with or sometimes even lower than their MB counterparts. Shen et al.[23] reported the midterm outcomes of 34 cemented PS-TKRs in each group with a mean follow-up of 5.9 years. No significant differences were found between the two groups concerning HSS scores, ROM, clinical and radiographic parameters measured, and survival rates in the Chinese population. The long-term results of all-poly TKA in our study are comparable in terms of KSS, WOMAC score, ROM, clinical and radiological features, and survival rate with MB components, within observable limits, despite the Asian lifestyle involving more bending of the knee and sitting cross-legged, compared to western literature.[22–25] Moreover, Ryan et al.[25] found that implementing an AP tibia can significantly impact both surgical costs and overall hospital admission expenses, while still maintaining comparable 90-day outcome metrics.

Poor results in the AP group in the past were more likely related to technical errors in obtaining proper implant alignment rather than the absence of a metal component. This is certainly not true with modern instrumentation. All-polyethylene components are technically demanding because the stability and activity of the knee must be assessed simultaneously during trial reduction. The AP components should be hand-pressed as much as possible, and hammering should be kept at a minimum to prevent damage to the polyethylene. Posterior cement removal from the all-poly component is to be meticulously performed to prevent cementophyte formation; after implantation, a thorough wash is to be performed to remove invisible debris from the joint, which may be the trigger for aseptic loosening. With these technical modifications, the AP tibia results were equal to or better than those of the MB tibia components.

The study has a few limitations: The possibility of bias IN patient recall, the fact that generalization could not be ascertained since it was conducted in a single institution, and the loss to follow-up in 5% of the AP group and 3% of the MB group may have skewed the results. Definitive conclusions about comparative risks are limited by the small number of infections and revision events. Economic constraints in the study setting may limit its applicability to other regions. All of the following may influence outcomes: variations in surgical technique, surgeon experience, and specific components of lifestyle activities in the Indian population, including squats and cross-legged sitting. This result could also have been influenced by uncontrolled factors, such as comorbidities and variations in postoperative rehabilitation, which were not assessed. This study emphasizes how important it is to have precise surgical technique and postoperative care, especially when performing culturally unique activities like sitting cross-legged and squatting, in order to maximize patient outcomes.

Conclusion

Long-term results of modular MB and AP tibial components in TKR showed that both designs were successful in significantly reducing pain and improving function in the Indian population. Modern AP implants show clinical, radiological, and functional outcomes comparable to, and slightly better than, their MB counterparts in terms of functional outcomes, with improved functional scores, ROM, and reduced or no backside poly wear leading to aseptic loosening, despite early misgivings about AP components due to early design flaws and technical challenges. This is especially true when considering their cost-effectiveness in resource-constrained settings. More long-term, prospective multicenter trials are necessary to confirm these results and to shape clinical practice guidelines that support lasting, reasonably priced options for all-poly TKR.

Orcid

Ravikumar Mukartihal https://orcid.org/0000-0001-7280-126X
Manideep Reddy R https://orcid.org/0009-0007-1644-510X

References

1. Ducheyne P, Kagan A II, Lacey JA. Failure of total knee arthroplasty due to loosening and deformation of the tibial component. J Bone Joint Surg Am 1978;60(3):384–391. PMID: 649643.
2. Gioe TJ, Maheshwari AV. The all-polyethylene tibial component in primary total knee arthroplasty. J Bone Joint Surg Am 2010;92(2):478–487. DOI: 10.2106/JBJS.I.00842.
3. Kurtz SM, Ong KL, Lau E, et al. International survey of primary and revision total knee replacement. Int Orthop (SICOT) 2011;35:1783–1789. DOI: 10.1007/s00264-011-1235-5.
4. Hamilton LR. UCI total knee replacement. A follow-up study. J Bone Joint Surg Am 1982;64(5):740–744. PMID: 7085700.

5. Murase K, Crowninshield RD, Pedersen DR, Chang TS. An analysis of tibial component design in total knee arthroplasty. J Biomech 1983;16(01):13–22. DOI: 10.1016/0021-9290(83)90042-8.
6. Robertsson O, Lidgren L, Sundberg M, W-Dahl A. The Swedish Knee arthroplasty register—Annual report 2020.
7. Apostolopoulos V, Nachtnebl L, Mahdal M, Pazourek L, Boháč P, Janíček P, et al. Clinical outcomes and survival comparison between NexGen all-poly and its metal-backed equivalent in total knee arthroplasty. Int Orthop. 2023.
8. Longo UG, Ciuffreda M, D'Andrea V, et al. All-polyethylene versus metal-backed tibial component in total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2017;25:3620–3636. PMID: 1959277.
9. Gudnason A, Hailer NP, W-Dahl A, et al. All-polyethylene versus metal-backed tibial components—An analysis of 27,733 cruciate-retaining total knee replacements from the Swedish Knee Arthroplasty Register. J Bone Joint Surg 2014;96:994–999. DOI: 10.1016/s0883-5403(06)80094-x.
10. Gustke KA, Gelbke MK. All-polyethylene tibial component use for elderly, low-demand total knee arthroplasty patients. J Arthroplasty 2017;32:2421–2426. DOI: 10.2106/00004623-200303000-00014.
11. Kendall J, Pelt CE, Imlay B, et al. Revision risk for total knee arthroplasty polyethylene designs in patients 65 years of age or older: An analysis from the American joint replacement registry. J Bone Jt Surg 2022;104:1548–1553. DOI: 10.2106/JBJS.21.01251.
12. Apel DM, Tozzi JM, Dorr LD. Clinical comparison of all polyethylene and metal backed tibial components in total knee arthroplasty. Clin Orthop 1991;273:243–252. PMID: 1959277.
13. Rand JA. Comparison of metal-backed and all-polyethylene tibial components in cruciate condylar total knee arthroplasty. J Arthroplasty 1993;8(3):307–313. DOI: 10.1016/s0883-5403(06)80094-x.
14. Faris PM, Ritter MA, Keating EM, et al. The AGC all polyethylene tibial component: A ten-year clinical evaluation. J Bone Joint Surg Am 2003;85(03):489–493. DOI: 10.2106/00004623-200303000-00014.
15. Scuderi GR, Insall JN, Windsor RE, et al. Survivorship of cemented knee replacement. J Bone Joint Surg Br 1989;71(5):798–803. DOI: 10.1302/0301-620X.71B5.2584250.
16. Dwards SA, Pandit HG, Ramos JL, et al. Analysis of polyethylene thickness of tibial components in total knee replacement. J Bone Joint Surg Am 2002;84(3):369–371. DOI: 10.2106/00004623-200203000-00006.
17. GA Engh, KA Dwyer, CK Hanes. Polyethylene wear of metal-backed tibial components in total and unicompartmental knee prostheses. J Bone Joint Surg Br 1992;74(1):917. DOI: 10.1302/0301-620X.74B1.1732274.
18. RC Wasielewski , JO Galante. Wear patterns on retrieved polyethylene tibial inserts and their relationship to technical considerations during total knee arthroplasty. Clin Orthop Relat Res 1994:299:31–43. PMID: 8119035.
19. Schai PA, Thornhill TS, Scott RD. Total knee arthroplasty with the PFC system. Results at a minimum of ten years and survivorship analysis. J Bone Joint Surg Br 1980;80(5):850–858. DOI: 10.1302/0301-620x.80b5.8368.
20. Wright TM, Rimnac CM, Stulberg SD, et al. Wear of polyethylene in total joint replacements. Observations from retrieved PCA knee implants. Clin Orthop Relat Res 1992;276:126–134. PMID: 1537143.
21. Adalberth G, Nilsson KG, Bystrom S, et al. Low-conforming all-polyethylene tibial component not inferior to metal-backed component in cemented total knee arthroplasty. Prospective, randomized radiostereometric analysis study of the AGC total knee prosthesis. J Arthroplasty 2000;15:783–792. DOI: 10.1054/arth.2000.8101.
22. Norgren B, Dalén T, Nilsson KG. All-poly tibial component better than metal-backed: A randomized RSA study. Knee 2004;11(3):189–196. DOI: 10.1016/S0968-0160(03)00071-1.
23. Shen B, Yang J, Zhou Z, et al. Survivorship comparison of all-polyethylene and metal-backed tibial components in cruciate-substituting total knee arthroplasty—Chinese experience. Int Orthop 2009;33(5):1243–1247. DOI: 10.1007/s00264-008-0634-8.
24. Shaho Hasan S, Marang-Van De Mheen PJ, Kaptein BL, et al. Allpolyethylene versus metal-backed posterior stabilized total knee arthroplasty: Similar 2-year results of a randomized radiostereometric analysis study. Acta Orthop 2019;90:590–595. DOI: 10.1080/17453674.2019.1668602.
25. Ryan SP, Steele JR, Plate JF, et al. All-polyethylene tibia: an opportunity for value-based care in bundled reimbursement initiatives. Orthopedics 2021;44:e114–e118. DOI: 10.3928/01477447-20201009-01.

RESEARCH ARTICLE

A Simple Subjective Surgical Complexity Score for Surgical Planning in Total Knee Arthroplasty Helps to Improve Surgical Efficiency and Reduce Costs

Amar S Vadhera[1], Joseph Koressel[2], Cynthia E Law [3], Matthew Stein[4], Neil P Sheth[5]

Received on: 12 July 2024; *Accepted on:* 07 August 2024; *Published on:* 01 October 2024

Abstract

Background: Efficient operating room (OR) management reduces the potential for extended OR days. Surgical schedulers play a key role in generating OR schedules, despite unfamiliarity with specific case considerations that may affect case length. We evaluated the correlation between a single surgeon's subjective preoperative complexity scoring system and the resulting total knee arthroplasty (TKA) procedure time, and secondarily to assess the financial losses generated from unaccounted OR time.

Methods: All patients at the index institution who received a primary, unilateral TKA from February 2014 to November 2019 with a documented tourniquet time and assigned complexity score were included ($n = 551$). Patient and surgery-specific characteristics were recorded, including the score that was assigned at the preoperative visit. Case length was determined by tourniquet time. The rate of underestimating room duration was estimated from the booking time. Average supply and labor costs as well as surgical and anesthesia charges were tabulated across four providers (one utilizing the score and three not utilizing the score).

Results: Preoperative complexity score was positively correlated with tourniquet time ($p < 0.001$, $\rho = 0.196$). Operations with complexity scores of 1, 2, and 3 had a mean tourniquet time of 59 minutes, 64.2 minutes, and 76 minutes, respectively ($p < 0.001$). The surgical assistant training level did not correlate with a longer tourniquet time ($p = 0.492$). The attending utilizing the score only underestimated the booking time at a rate of 4% with a significantly shorter room duration (131 minutes) while the remaining attendings underestimated the required booking time at a rate of 72% with a longer room duration (151 minutes; $p < 0.05$). The average cost savings per case between attendings that did not use the complexity score and the attending that did was $4,462.17 ($223.11 per minute).

Conclusion: Our complexity score correlated with OR time and may aid in enhancing OR efficiency by incorporating it into scheduling algorithms, and reducing the direct variable operating cost burden of primary TKAs.

Keywords: Complexity score, Efficiency, Knee arthroplasty, Operative time, Scheduling.

Indian Journal of Arthroplasty (2024): 10.5005/ijoa-11025-0005

Introduction

The number of primary total knee arthroplasty (TKA) is rapidly growing in the United States, projected to reach 935,000 procedures annually by 2030.[1] Concurrently, medicare reimbursement rates for TKA have reduced by 1.7% per year since 2000 after adjusting for inflation.[2] As such, the overall cost of delivering quality care for total joint arthroplasties continues to rise at a rate that outpaces Medicare reimbursement rates.[3] Reducing profit margins for TKAs, coupled with rising operating room (OR) costs at approximately $80/min,[4] underscore the need to maximize surgical efficiency.

Proper surgical scheduling reduces the number of extended OR days and enhances surgical efficiency. Operating room schedulers are routinely tasked with generating procedural schedules notwithstanding their unfamiliarity with surgical considerations inherent to the patients scheduled. Further, they often rely on institution metrics, notably the average surgical time for the most recent 10 cases of a matching common procedural terminology (CPT) code, when estimating case duration and the number of cases that can be completed on a given OR day. In tandem, this introduces heavy bias and inaccuracies in the scheduling process since all TKA procedures, regardless of complexity, share a single CPT code (i.e., 27447).[5] For instance, conversion TKA, which does not have a distinct CPT code, takes significantly longer to complete

[1]Sidney Kimmel Medical College, Philadelphia, Pennsylvania, United States of America

[2]Department of Orthopaedic Surgery, Stanford University, Palo Alto, California, United States of America

[3]Pennsylvania Hospital, Philadelphia, Pennsylvania, United States of America

[4,5]Department of Orthopaedics, University of Pennsylvania, Pennsylvania Hospital, Philadelphia, Pennsylvania, United States of America

Corresponding Author: Amar S Vadhera, Sidney Kimmel Medical College, Philadelphia, Pennsylvania, United States of America, Phone: +215 3165151, e-mail: amarvadhera@gmail.com

How to cite this article: Vadhera AS, Koressel J, Law CE, *et al*. A Simple Subjective Surgical Complexity Score for Surgical Planning in Total Knee Arthroplasty Helps to Improve Surgical Efficiency and Reduce Costs. Indian J Arthroplasty 2024;1(1):7–12.

Source of support: Nil

Conflict of interest: Dr Neil P Sheth is associated as the International Editorial Board member of this journal and this manuscript was subjected to this journal's standard review procedures, with this peer review handled independently of this editorial board member and his research group.

Table 1: Novel surgical complexity score

1	A standard TKA with a flexible coronal deformity, flexion contracture <10°, BMI <35, and normal bone stock.
2	Meet one of the following criteria: significant coronal deformity (10–25° varus/valgus), a non-correctable deformity (e.g., fixed valgus deformity), a flexion contracture between 10 and 25°, BMI >35, retained hardware (e.g., conversion TKA), and the presence of specific comorbidity that compromises the patient's bone quality and/or soft-tissue sleeve (e.g., severe osteoporosis, inflammatory arthritis, hemophilia).
3	Patients with more exaggerated circumstances: Sagittal or coronal deformity >25°, flexion contracture > 25°, significant femoral and/or tibial bone loss, and diagnoses requiring a more constrained implant (e.g., post-polio syndrome).

compared to standard TKA (102.1 minutes vs 71.7 minutes);[6] it is, therefore, imperative that details regarding surgical procedures must be included in estimating case duration. Robust and inclusive analysis by surgical scheduling teams will not only more accurately predict the operative time needed for any particular case, but may also result in a higher number of cases being performed and improved access to patient care.

Nearly all demographic factors have been associated with increased surgical time for primary TKAs, including younger age, obesity, increased American Society of Anesthesiologists (ASA) score, male gender, and tobacco use.[7–10] However, no prior investigations have evaluated surgery-specific factors that influence operative time, such as the presence of previous hardware or knee deformity, which has been already assessed by the attending surgeon. The amalgam of the subjective surgeon assessment, which considers the aforementioned patient factors, may lead to a more accurate estimate of operative time, and consequently, facilitate accurate scheduling of both routine and complex surgical cases, enhancing surgical efficiency and reducing costs for the institution.

The purpose of this study was to describe a novel, surgeon-driven preoperative complexity scoring system and evaluate its effectiveness in predicting TKA procedure time and facilitating efficient scheduling of cases on any given OR day. Secondarily, we sought to determine the cost savings associated with the utilization of this scoring system. We hypothesized that a simple, subjective orthopedic surgical complexity score would be able to accurately predict the intraoperative time required for performing a TKA, thereby reducing unscheduled operative time and overall costs.

Methods

A retrospective chart review of all primary, consecutive, unilateral TKA performed by a single fellowship-trained surgeon (senior author) at a tertiary hospital from February 2014 to November 2019 was conducted. Patients who were classified using preoperative complexity score were included in the study. Cases were excluded due to the absence of a preoperative complexity score ($n = 99$) or inadequate anesthesia documentation ($n = 1$). Of the 651 patients identified, 551 (85%) were included for analysis.

All TKAs were performed under tourniquet through a mid-vastus approach using cemented, cruciate retaining implants. Patient age, gender, ASA status, comorbidities, body mass index (BMI), and anesthesia type (spinal vs general) were manually reviewed from the anesthesia documentation. To ensure that the majority of determinants of operative time were captured, the presence of preexisting hardware (i.e., Conversion TKA) was also recorded. Procedure time was the primary endpoint in this study and was defined as the time in which the patient entered the operative room to the time they left (i.e., wheels in to wheels out). No changes in working system coordination, procedural preparation, or physical therapist and nursing staffing were made during the duration of the study to control for other factors affecting surgical efficiency.

A simple, subjective complexity score was formulated based on the anticipated operative duration, considering the surgical complexity of the patient and procedure. For ease of use, this was a 3-point Likert scale, with a lower score representing a less complex case, and *vice versa*. The preoperative complexity score was documented in the patient progress note by the attending following the preoperative office appointment. A level 1 case has an anticipated procedure time of <60 minutes (tourniquet time) and a booked time of <120 minutes. A patient was classified as a level 2 case if they present with potential technical challenges (e.g., obesity, mild to moderate deformity) or patient comorbidity that directly impacted the patient's surgical management, with an anticipated operative time of 60–120 minutes and booked time of 120–180 minutes. The highest complexity score of 3 was assigned to patients with more exaggerated circumstances (e.g., severe deformity, prior hardware), with an anticipated operative time of >180 minutes and booked time of 180–240 minutes. Complete details regarding the criteria of each complexity level are detailed in Table 1.

As a control group for cost comparison, we compared the average supply and labor costs of the study cohort mentioned above to a control cohort of 488 primary TKAs performed at the same tertiary hospital by three other attending physicians at an equivalent level experience between January 2018 and November 2019. Unlike the three surgeons, only the senior author employed the surgical complexity score to assist with preoperative scheduling. The specified timeframe was selected as this was the earliest date following the decision to remove TKA from the inpatient-only list.[11] Labor costs were defined as wages and benefits of the OR clinical staff, not accounting for nurse anesthetist, anesthesiologist, surgeon, resident, or radiology costs. Average labor cost was calculated by multiplying the average procedure duration in minutes by cost per minute. Surgical and anesthesia charges as well as average procedure duration were subsequently tabulated. There were no significant variations in surgical technique, implant distribution, cementing protocol, or technological use for the patients treated among the four surgeons. Further, no unplanned events occurred perioperatively during this procedure.

Descriptive statistics were calculated for all variables. Spearman correlation assessed the relationship between complexity score and tourniquet time. Shapiro–Wilk normality testing was applied to evaluate the normality of the complexity score and another preoperative variable as a function of tourniquet time. Depending on normality, group comparisons were performed using either the independent samples t-test or the Mann–Whitney U test. For variables with more than two groups, the one-way Kruskal–Wallis or ANOVA test was used. A multiple logistic regression model was created to determine the independent association between complexity score and tourniquet time while controlling for all patient characteristics and collected preoperative factors. All analysis was completed using RStudio software, with a significance level set at $p < 0.05$.

Results

A total of 551 patients were included. Mean age was 62.3 years (range, 17.2–86.3 years), 69.7% were female, and mean BMI was 31.9 kg/m^2 (range, 15.6–53.3 kg/m^2). Patient demographics are summarized in Table 2.

There were significant differences between complexity score groups with regard to tourniquet time. Patients with a complexity score of 1 had a significantly lower mean tourniquet time (59 minutes; CI: 56.8–61.2) than those with a score of 2 (64.2 minutes; CI: 62.2–66.3) and those with a score of 3 (76 minutes; CI: 66.6–85.4)

Table 2: Patient demographics of the cohort

Variable	*Overall (n = 551)*
Age (years)	
Mean (SD)	62.2 (11.6)
Median (min, max)	62.3 (17.2, 86.3)
<65	325 (58.6%)
>65	230 (41.4%)
Sex	
Female	387 (69.7%)
Male	168 (30.3%)
Smoking status	
Non-smoker	447 (80.5%)
Smoker	108 (19.5%)
Race/Ethnicity	
Asian	20 (3.6%)
African American	229 (41.3%)
Hispanic/Latinx	18 (3.2%)
Other	21 (3.8%)
White	267 (48.1%)
ASA classification	
I	6 (1.1%)
II	315 (56.8%)
III	229 (41.3%)
IV	5 (0.9%)
Anesthesia	
General	143 (25.8%)
Spinal	412 (74.2%)
DM-2 status	
No	462 (83.2%)
Yes	93 (16.8%)
Bleeding disorder	
Not present	548 (98.7%)
Present	7 (1.3%)
HTN	
Not present	209 (37.7%)
Present	346 (62.3%)
COPD	
None	528 (95.1%)
Present	27 (4.9%)
Surgical assistant	
Physician assistant	21 (3.8%)
Resident	302 (54.4%)
Fellow	232 (41.8%)
Surgical complexity score	
I	197 (35.5%)
II	327 (58.9%)
III	31 (5.6%)
Valgus deformity	
Not present	471 (84.9%)
Present	84 (15.1%)
Tight varus	
Not present	521 (93.9%)
Present	34 (6.1%)
Flexion contracture	
Not present	541 (97.5%)
Present	14 (2.5%)
Hypoplastic lateral femoral condyle	
Not present	554 (99.8%)
Present	1 (0.2%)
Conversion total knee arthroplasty	
No	539 (97.1%)
Yes	16 (2.9%)
Revision total knee arthroplasty	
No	555 (100%)
Yes	0 (0.0%)
Arthrofibrosis	
Not present	554 (99.8%)
Present	1 (0.2%)
Distal femur flexion contracture	
Not Present	554 (99.8%)
Present	1 (0.2%)
Significant deformity	
Not Present	543 (97.8%)
Present	12 (2.2%)
BMI	
Mean (SD)	32.0 (6.64)
Median (min, max)	31.4 (15.6, 53.3)
<30	224 (40.4%)
30–35	164 (29.5%)
35–40	89 (16.0%)
40+	78 (14.1%)
Preoperative hemoglobin level	
Mean (SD)	13.3 (1.34)
Median (min, max)	13.4 (8.30, 17.2)
Estimated blood loss	
Mean (SD)	80.5 (43.5)
Median (min, max)	75.0 (15.0, 400)
Tourniquet time	
Mean (SD)	63.1 (18.5)
Median (min, max)	59.0 (15.0, 130)

(Contd...)

Table 2: *(Contd...)*

Variable	*Overall (n = 551)*
Cement time	
Mean (SD)	47.6 (15.9)
Median (min, max)	44.0 (15.0, 105)
Minutes from start to closure	
Mean (SD)	63.6 (18.7)
Median (min, max)	59.0 (26.0, 180)

ASA, American Society of Anesthesiology Physical Status; BMI, body mass index; COPD, chronic obstructive pulmonary disease; DM-2, diabetes mellitus type 2; HTN, hypertension

($p < 0.001$ for both pairwise comparisons). In addition, patients with a score of 2 had a significantly lower mean tourniquet time than those with a score of 3 ($p < 0.05$).

A multivariate logistic regression model incorporating all collected patient characteristics and preoperative factors was constructed to identify modifiable characteristics that were independently associated with tourniquet time (Table 3). This model demonstrated a statistically significant association between complexity score and time, with an additional increase in time by 5.38 minutes (CI: 2.77–7.99, $p < 0.001$) for every increase in complexity level. There was also a significant association between race and tourniquet time, with an additional increase in time of 4.51 minutes (CI: 1.11–7.91, $p = 0.01$) for white patients and 7.42 minutes (CI: 2.41–12.43, $p = 0.004$) for African American patients compared to patients of other races. Furthermore, there was a significant association between tourniquet time and age group as well as sex, with a decrease in tourniquet time by 3.83 minutes (CI: –8.44 to –1.76), $p = 0.003$) for patients greater than 65 years old relative to younger patients, and a decrease by 8.00 minutes (CI: –11.21 to –4.78), $p < 0.001$) for females compared to males.

In the cost analyses, the average surgical charges for a primary TKA were $5,297 for the first 30 minutes of OR time and $3,584 for each additional 30 minutes. ($175.57/min and $119.47/min, respectively). The average anesthesia charges were $3,048 for the first 30 minutes and $3,048 for each additional 30 minutes ($101.60/min). The average supply costs across all four surgeons were $4,714.51 per case and the average labor costs were $1,116.17 per case. The senior author who employed the surgical complexity score experienced decreased average supply and labor cost ($p < 0.05$ for both) compared to the other three surgeons (Fig. 1). Furthermore, the use of the surgical complexity score allowed for under-scheduling of room duration for the procedure at a rate of 4% with an average duration of 131 minutes; the control group of three attendings that did not utilize the scoring system under-scheduled the room duration for the procedure at an average rate of 72% with an average duration of 151 minutes. The estimated cost savings per minute when utilizing the surgical complexity score was $4,462.17 ($223.11 per minute).

Table 3: Multivariate linear regression model to assess the association between patient characteristics, preoperative factors, and surgical complexity score with tourniquet time as the dependent variable

Variable	*Beta coefficient*	*95% Confidence interval*	*p-value*
Surgical complexity score	5.38	2.77–7.99	<0.001*
Reference: Age <65 years			
Age >65 years	–4.92	–8.19 – –1.65	0.003*
Reference: Male			
Female	–8.00	–11.21 – –4.78	<0.001*
Reference: Non-smoker			
Smoker	–0.10	–4.02 – 3.83	0.96
Reference: Spinal anesthesia			
General anesthesia	0.25	–4.27 – 3.88	0.89
Reference: Non-diabetic			
Diabetic	–0.19	–4.27 – 3.88	0.93
Reference: No bleeding disorder			
Bleeding disorder	2.02	–11.19 – 15.22	0.76
Reference: No hypertension			
Hypertension	–0.64	–3.89 – 2.61	0.70
Reference: No COPD			
COPD	–0.35	–7.17 – 6.48	0.92
Reference: ASA <2			
ASA >3	–0.56	–3.70 – 2.58	0.73
Reference: Other races**			
Race: White	4.51	1.12–7.91	0.01*
Race: African American	7.42	2.41–12.43	0.004*
BMI	0.23	–0.01 – 0.47	0.07
Estimated blood loss	0.03	–0.01 – 0.06	0.13

*Indicates statistical significance at $p < 0.05$ level. **Other races include Asian, Hispanic/Latino, East-Indian, or Other Pacific Islander. BMI, body mass index

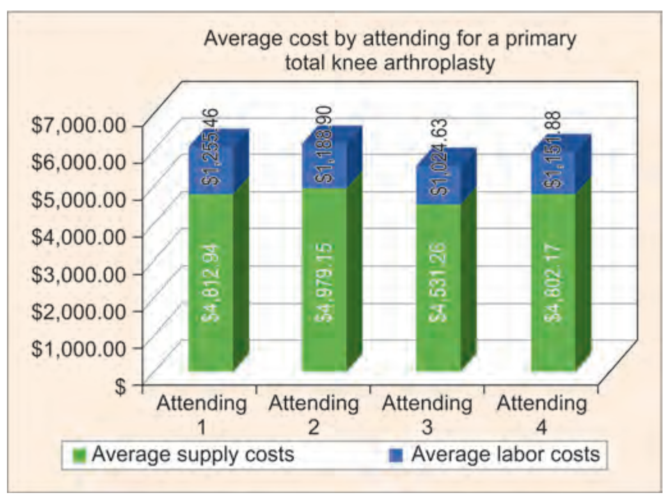


Fig. 1: Average supply and labor costs across four attending physicians. Attending #3 utilized the surgical complexity score

Discussion

This study found that a preoperative surgical complexity scoring system could accurately predict operative time in TKA. Surgeons factor in both patient-specific and technical surgical elements when estimating OR time, which are not currently utilized by surgical schedulers. Our study emphasizes the value of a preoperative complexity score in accurately predicting case duration, improving communication between surgeons and schedulers, and optimizing OR efficiency to reduce the overall costs associated with the procedure.

Utilizing surgical factors to accurately predict case length can help to optimize surgical suite utilization and reduce the amount of extended OR days for provider teams. On average, surgeons wait an average of 51 minutes between cases (also known as turnover time) and up to 29.5 hours of turnover time per month.[12] The shift in OR scheduling from a first-come, first-served approach to using historical averaging has optimized OR throughput and reduced resource underutilization across surgical specialties.[13,14] Now with machine learning, authors can successfully predict case length within 10% of the actual duration.[15] Further, by incorporating surgeons' own estimates, predictive models have become more accurate relying solely on historical averages.[16] Notably, Eijkeman et al. found that surgeons' estimates were the most important predictors of total OR time in the context of general surgery.[17] Although historical averages of primary TKA are key predictors of surgical time, incorporating surgeon experience through subjective estimation and objective surgical factors is the natural next step to capitalize on hours of time wasted by provider teams.[18]

A key reason why schedulers do not have the resources to include surgical factors in case duration estimations is that CPT codes for a specific procedure are highly generalized and non-specific. Common procedural terminology codes fail to account for the complexity of cases and instead rely on complexity qualifiers that are outside the scope of a scheduler's training.[19] The current investigation demonstrated that such uncaptured variation is often anticipated by the provider team. The preoperative subjective score alone does not predict exact surgical times, but rather, allows surgeons to seamlessly share their subjective estimates to schedules in an organized fashion. In practice, weekly multidisciplinary team meetings communicating the difficulty of a case with this simple scoring system as well as the reason for complexity categorization could streamline communication with all members of the surgical team, enabling them to make the necessary perioperative preparations needed to minimize turnover time and avoid unnecessarily long operative days.

The surgical complexity score was the strongest predictor of case length relative to all included demographic and surgical factors. These secondary predictors demonstrated only a small effect size which did not account for surgery-specific differences; this is consistent with other research that demonstrate variations in OR time by patient characteristics.[8–10] While the literature describes these predictors of OR time, limited strides have been made to improve OR efficiency based on perioperative and intraoperative changes. When successful, such workflow analyses and perioperative care strategy optimization have led to a 29% increase in volume per OR per day and decreased overall surgical time per case.[20,21] More importantly, our study showed that the senior author only underestimated the necessary booking time at a rate of 4%, whereas the comparative group of attendings underestimated their time in 72% of cases. While efforts to reduce case length are important, an accurate prediction of surgical case length may impact OR efficiency to a greater extent.

Cost savings associated with utilizing the simple surgical complexity score were approximately $4,500 per case ($223.11 per minute). With the declining revenue generated from TKA, minimizing the cost burden is important in keeping practices fiscally solvent.[22] Multiple investigations have attempted to assess the average cost per minute of performing a TKA, with estimates ranging from $22/min to $133/min.[4,23–25] However, these studies do not encompass the surgical and anesthesia charges associated with the procedure to quantify the mixed cost burden per minute associated with the case. Ryan et al. concur with the notion that a complexity score for primary TKAs is necessary to both offset high operational costs per minute and integrate into future reimbursement models as a case modifier metric.[26] Surgical delays have been directly linked to an approximate 40% increase in overhead practice costs, stressing the economic need to align reimbursement and case complexity by enhancing OR efficiency.[27] Even though this cost analysis is preliminary, integrating the proposed surgical complexity scoring system into practice may translate into substantial reductions in not only OR duration, but also in direct variable costs. As such, this article aims to highlight the economic benefits of creating organizational efficiency standards that hospital systems should implement to maximize their procedural margins; future research within the orthopedic field may investigate these implications further. Nonetheless, we present this practical use—case of a necessary TKA scoring system as a proof of concept for future optimization of case management in orthopedic practices.

This study represents the initial data of a novel scoring system for estimating OR length and should be interpreted in light of some limitations. The criteria underlying the three-point scoring system may limit the generalizability and reproducibility of the score as it is derived from the sole experience of a single provider. Nonetheless, the subjective nature of the score was designed to permit individualization at the surgeon level, allowing the surgeon to incorporate their own unique practice considerations and intrinsic experiences with their client population. Consequently, surgeon experience would be the primary driver of predicted surgical time whilst incorporating several patient factors that general operational metrics (e.g., average time of preceding 10 cases). However, we included only surgeons with equal experience to mitigate this bias. We believe that this subjective score would be all-encompassing and hence be a more useful predictor of OR time. This association may be even more apparent in revision TKA wherein surgical complexity is substantially greater.

Conclusion

A novel surgical complexity scoring system was highly correlated with OR time for primary TKA, demonstrating successful implementation with case scheduling algorithms as well as improved OR utilization and efficiency. Additionally, an estimated $4,500 per minute in cost savings was realized when utilizing the complexity scoring system. While initial adoption may be met with lukewarm enthusiasm, individualization of the scoring system by practice standards and working within a consistent care team could help streamline preoperative scheduling, enhance OR efficiency, and reduce costs.

References

1. Sloan M, Premkumar A, Sheth NP. Projected volume of primary total joint arthroplasty in the U.S., 2014 – 2030. J Bone Jt Surg – Am Vol 2018;100(17):1455–1460. DOI: 10.2106/JBJS.17.01617.
2. Mayfield CK, Haglin JM, Levine B, et al. Medicare reimbursement for hip and knee arthroplasty from 2000 to 2019: An unsustainable trend. J Arthroplasty 2019. DOI: 10.1016/j.arth.2019.12.008.
3. Scott WN, Booth RE, Dalury DF, et al. Efficiency and economics in joint arthroplasty. J Bone Jt Surg 2009;91(SUPPL. 5):33–34. DOI: 10.2106/JBJS.I.00365.

4. Macario A. What does one minute of operating room time cost? J Clin Anesth 2010;22(4):233–236. DOI: 10.1016/j.jclinane.2010.02.003.
5. Kayis E, Wang H, Patel M, et al. Improving prediction of surgery duration using operational and temporal factors. AMIA Annu Symp Proc 2012;2012:456–462. PMID: 23304316.
6. Kreitz TM, Deirmengian CA, Penny GS, et al. A current procedural terminology code for "knee conversion" is needed to account for the additional surgical time required compared to total knee arthroplasty. J Arthroplasty 2017;32(1):20–23. DOI: 10.1016/j.arth.2016.06.040.
7. Dhupar R, Evankovich J, Klune JR, et al. Delayed operating room availability significantly impacts the total hospital costs of an urgent surgical procedure. Surgery 2011;150(2):299–305. DOI: 10.1016/j.surg.2011.05.005.
8. George J, Mahmood B, Sultan AA, et al. How fast should a total knee arthroplasty be performed? An analysis of 140,199 surgeries. J Arthroplasty 2018;33(8):2616–2622. DOI: 10.1016/j.arth.2018.03.012.
9. Acuña AJ, Samuel LT, Karnuta JM, et al. What factors influence operative time in total knee arthroplasty? A 10-year analysis in a national sample. J Arthroplasty 2019. DOI: 10.1016/j.arth.2019.10.054.
10. Bradley BM, Griffiths SN, Stewart KJ, et al. The effect of obesity and increasing age on operative time and length of stay in primary hip and knee arthroplasty. J Arthroplasty 2014;29(10):1906–1910. DOI: 10.1016/j.arth.2014.06.002.
11. Iorio R. Total knee arthroplasty removal from the medicare inpatient-only list: Implications for surgeons, patients, and hospitals: Introduction. J Arthroplasty 2020;35(6S):S22–S23. DOI: 10.1016/j.arth.2020.02.005.
12. Sedlack JD. The Utilization of Six Sigma and statistical process control techniques in surgical quality improvement. J Healthc Qual 2010;32(6):18–26. DOI: 10.1111/j.1945-1474.2010.00102.x.
13. Dexter F, Abouleish AE, Epstein RH, et al. Use of operating room information system data to predict the impact of reducing turnover times on staffing costs. Anesth Analg 2003;97(4):1119–1126, table of contents. DOI: 10.1213/01.ane.0000082520.68800.79.
14. Smith CD, Spackman T, Brommer K, et al. Re-engineering the operating room using variability methodology to improve health care value. J Am Coll Surg 2013;216(4):559–568 DOI: 10.1016/j.jamcollsurg.2012.12.046.
15. Bartek MA, Saxena RC, Solomon S, et al. Improving operating room efficiency: Machine learning approach to predict case-time duration. J Am Coll Surg 2019;229(4):346–354.e3. DOI: 10.1016/j.jamcollsurg.2019.05.029.
16. Wu A, Weaver MJ, Heng MM, et al. Predictive model of surgical time for revision total hip arthroplasty. J Arthroplasty 2017;32(7):2214–2218. DOI: 10.1016/j.arth.2017.01.056.
17. Eijkemans MJC, van Houdenhoven M, Nguyen T, et al. Predicting the unpredictable: A new prediction model for operating room times using individual characteristics and the surgeon's estimate. Anesthesiology 2010;112(1):41–49. DOI: 10.1097/ALN.0b013e3181c294c2.
18. Wu A, Huang C-C, Weaver MJ, Urman RD. Use of historical surgical times to predict duration of primary total knee arthroplasty. J Arthroplasty 2016;31(12):2768–2772. DOI: 10.1016/j.arth.2016.05.038.
19. Bergen MA, Ryan SP, Hong CS, et al. Conversion total knee arthroplasty: A distinct surgical procedure with increased resource utilization. J Arthroplasty 2019;34(7S):S114–S120. DOI: 10.1016/j.arth.2019.01.070.
20. Attarian DE, Wahl JE, Wellman SS, et al. Developing a high-efficiency operating room for total joint arthroplasty in an academic setting. Clin Orthop Relat Res 2013;471(6):1832–1836. DOI: 10.1007/s11999-012-2718-4.
21. Krasner H, Connelly NR, Flack J, et al. A multidisciplinary process to improve the efficiency of cardiac operating rooms. J Cardiothorac Vasc Anesth 1999;13(6):661–665. DOI: 10.1016/s1053-0770(99)90116-7.
22. Lonner JH, Goh GS, Sommer K, et al. Minimizing surgical instrument burden increases operating room efficiency and reduces perioperative costs in total joint arthroplasty. *j arthroplasty* 2021;36(6):1857–1863. DOI: 10.1016/j.arth.2021.01.041.
23. Fang CJ, Mazzocco JC, Sun DC, et al. Total knee arthroplasty hospital costs by time-driven activity-based costing: Robotic vs Conventional. Arthroplast Today 2021;13:43–47. DOI: 10.1016/j.artd.2021.11.008.
24. Volpin A, Khan O, Haddad FS. Theater cost is £16/minute so what are you doing just standing there? J Arthroplasty. 2016;31(1):22–26. DOI: 10.1016/j.arth.2015.08.008.
25. Lavernia CJ, Drakeford MK, Tsao AK, et al. Revision and primary hip and knee arthroplasty. A cost analysis. Clin Orthop Relat Res 1995;(311):136–141.PMID: 7634568.
26. Ryan SP, Wu CJ, Plate JF, et al. A case complexity modifier is warranted for primary total knee arthroplasty. J Arthroplasty 2021;36(1):37–41. DOI: 10.1016/j.arth.2020.07.066.
27. Koressel J, Shin M, Stein MK, et al. Pre-operative complexity scoring accurately predicts total knee arthroplasty operative time. University of Pennsylvania Orthopaedic Journal. 2021.

RESEARCH ARTICLE

Navigation-assisted vs Non-navigation-assisted Total Knee Replacement in Obese Patients: A Comparative Randomized Study

Mrinal Sharma[1], Muntashir Ashraf PK[2]

Received on: 15 July 2024; *Accepted on:* 14 September 2024; *Published on:* 01 October 2024

Abstract

Background: Obesity has also been recognized as the most important modifiable risk factor for osteoarthritis. Total knee replacement (TKR) in obese patients presents additional challenges with increased risk of component malpositioning and component loosening. Navigation in TKR results in accurate alignment, titrated soft tissue balancing, reduced blood loss, early rehabilitation, and reduced chances of embolism by not entering the intramedullary space. Whether it actually improves outcomes and reduces complications in obese was the research question of our study.

Materials and methods: It was a prospective randomized comparative observational study conducted at our institute between December 2017 and March 2019. Obese patients between ages 50 and 75 years undergoing primary TKR for osteoarthritis were included in the study after an internal review board approval and after prior informed consent. A hundred knees in obese patients [Body mass index (BMI) > 30 kg/m^2)] with varus deformation undergoing TKR were randomized into a navigated group (NG, n = 50) and a non-navigated group (NNG, n = 50).

Results: Patients were followed for a minimum of 2 years. The average follow-up was 4.6 years (2–6.5 years). Two of the patients (four knees) in NG were lost to follow-up and three of the patients (6 knees) had died in the NNG leaving us with a total of 46 knees in NG and 44 knees in NNG at final follow-up. The NG showed better outcomes in terms of alignment, component positioning, range of motion (ROM), deformity correction, blood loss, return to activity, and complications.

Conclusion: Computer navigation-assisted TKR significantly improves alignment with marginal functional improvement and reduces perioperative complications in obese patients.

Keywords: Functional outcome, Knee society score, Obesity, Navigation, Total knee replacement.

Indian Journal of Arthroplasty (2024): 10.5005/ijoa-11025-0006

Introduction

Obesity has been labeled as an epidemic by the World Health Organization and is an independent modifiable risk factor for the development of Osteoarthritis.[1–6] Overweight and obesity are seen in 30–65% of the adult urban population.[7] Osteoarthritis progresses at a much faster pace in obese and hence these patients tend to undergo joint replacement surgery at a comparatively younger age.[8,9]

World Health Organization classifies body mass index (BMI) greater than 30 as “obese” and that greater than 40 as “morbidly obese.”[10] Somehow obesity disproportionately affects knees more than hips, leading to an unequal increase in the number of primary total knee replacements (TKRs) compared to the number of total hip arthroplasties.[4] Obesity is associated with higher surgical complications, mortality, and increased healthcare costs.[11–14] There is an increased risk of component malposition and component loosening in obese patients undergoing TKR.[15] Computer-assisted surgery (CAS) in TKR results in an accuracy of bone cuts, precision in component placement as compared to conventional techniques, enables real-time kinematic analysis, and titration of soft tissue balancing. It also reduces blood loss and decreases the chances of fat embolism by not entering the intramedullary space. Enhanced soft tissue balancing has been shown to result in significant improvement in functional outcomes and knee scores.[16,17] To evaluate whether navigation improves outcomes in obese, we did a prospective randomized comparative study performing TKR in obese subjects with and without using navigation.

[1]Department of Orthopedics, Amrita Hospital, Faridabad, Haryana, India

[2]Department of Orthopedics, Kupwara Sub District Hospital, Jammu and Kashmir, India

Corresponding Author: Mrinal Sharma, Amrita Hospital, Faridabad, Haryana, India, Phone: +91 9910969298, e-mail: official.drmrinalsharma@gmail.com

How to cite this article: Sharma M, Ashraf MPK. Navigation-assisted vs Non-navigation-assisted Total Knee Replacement in Obese Patients: A Comparative Randomized Study. Indian J Arthroplasty 2024;1(1):13–20.

Source of support: Nil

Conflict of interest: Dr Mrinal Sharma is associated as Editor-in-Chief of this journal and this manuscript was subjected to this journal’s standard review procedures, with this peer review handled independently of the Editor-in-Chief and his research group.

Materials and Methods

It was a prospective randomized comparative observational study conducted at our institute between December 2017 and March 2019. Obese patients between ages 50 and 75 years undergoing primary TKR for osteoarthritis were included in the study after an internal review board approval and after prior informed consent. A hundred knees in obese patients (BMI > 30 kg/m^2) with varus deformation undergoing TKR were randomized into a navigated group (NG, n = 50) and a non-navigated group (NNG, n = 50). Randomization was done using the chit method (chits with NNG and NG written were taken out each time from a box and patients were accordingly allocated into groups). There were 22 females (18 bilateral and 4 unilateral knees) and 6 males (4 bilateral and 2 unilateral knees) in the NG and 18 females (16 bilateral and 2 unilateral knees) and 10 males (6 bilateral and 4 unilateral knees) in the NNG group. Female predominance was observed in both groups. The mean age was 62.91 years in the NNG and 62.18 years in the NG. The mean BMI in the NNG was 33.38 kg/m^2 (range 30.4–42.0) and that in the NG was 32.9 kg/m^2 (range 32.4–42.5). The two groups were comparable with respect to the average BMI (p-value 0.694), associated comorbidities, and deformities.

All patients were evaluated preoperatively with standard anteroposterior (AP) weight bearing and lateral radiographs of the knee. Coronal (varus/valgus) and sagittal (flexion/extension) plane deformities of the knee were assessed clinically with the help of a goniometer and plain radiographs. The knee range of motion (ROM), deformity, knee society score (KSS), and pain scores were assessed pre- and postoperatively at 12 weeks, 3 months, 6 months, and yearly. All preexisting comorbidities (79% in NNG and 76% in NG) were optimized. Preoperatively, apart from the preanesthetic checkup, all patients were assessed for hemoglobin (Hb), HbA1c (in diabetics), serum albumin levels, serum vit. D levels, and serum transferrin levels as markers of nutritional status. Same-day bilateral TKR was performed in 18 patients in NG and 18 patients in NNG. Those found unfit for a same-day bilateral TKR were operated in a staged manner at an interval of 6 weeks.

Surgical Technique

The standard medial parapatellar approach under combined spinal epidural anesthesia (bilateral TKR) and spinal plus femoral/adductor canal block was used (unilateral cases). Tourniquet was used for patients in both groups. Brainlab KNEE version 3.1 (Brainlab AG, Germany) was used for navigating during TKR. In a navigated TKR (Fig. 1), the inputs for the hip center of rotation, knee center, and ankle center were used by the computer to calculate the mechanical axis of the limb (Fig. 1B). A mapping of the proximal tibia and distal femoral geometry was done and navigation was guided to perform the proximal tibia and the distal femoral cut without violating the intramedullary canal (Figs 1C to F). The computer guides the surgeon to accurate implant alignment, rotation, sizing, and soft tissue balancing. Intraoperative readings of the navigated knee replacement were recorded (Figs 1B, C, E, H).

In a non-navigated TKR (Figs 2 and 3) routine bone cuts were performed using manual jigs. After soft tissue balancing and trialing, the final prosthesis cementing was done. The major problems faced were difficulty in joint exposure due to soft tissue (Fig. 2D and Fig. 3B), difficulty in hyperflexion and subluxating the tibia forward (so a femoral cut first technique was performed), difficulty in patellar eversion (so the patella was levered and seated into a subcutaneous pouch), problems in performing routine bony cuts and soft tissue balancing.

The patella was replaced in all patients except where the native patella was too thin or too small. A PFC sigma fixed bearing or an attune high flex fixed bearing prosthesis (Depuy Synthes, USA) was used in the patients. A tibial stem extender (n = 16; hybrid fixation) was used in patients with morbid obesity, soft bones, and where a bone defect was reconstructed (Figs 2F and H and Figs 3C and D).

The total tourniquet time was calculated. Postoperative knee X-rays were done to calculate alignment, component positioning, cementing, and signs of loosening. Alignment was defined as an "outlier" when there was a deviation of more than 3° from the median. On the AP films, α-alpha and β-beta angles (coronal alignment of the femoral and tibial components, respectively), and on lateral films, γ-gamma and σ-sigma angles (femoral flexion angle and tibial slope, respectively) were calculated.

Postoperatively hemoglobin was recorded on the second post-op day and compared with the preoperative value. The average fall in hemoglobin was compared in both the groups predicted the average intraoperative blood loss. All patients had received IV tranexamic acid (10 mg/kg body weight) at the time of induction to reduce bleeding and another dose was given 4 hours after surgery in the postoperative period. No drains were used in any case. So blood transfusion was never required in any patient in the groups. All patients received deep vein thrombosis (DVT) prophylaxis in the form of subcutaneous LMWH (40 mg/day started 12 hours from time to induction) for 5 days along with mechanical pumps. After this, the patient was put on oral aspirin 150 mg daily at bedtime for 15 days. All the patients were followed at 2 weeks, 6 weeks, 3 months 6 months, 1 year, and yearly thereafter.

The ROM of the knee joint was assessed at each follow-up and recorded at 12 weeks with the help of a goniometer. The knee assessment scoring for pain and function was done by KSS at 6 weeks, 3 months, 6 months, 1 year, and yearly at follow-up and compared with the preoperative KSS.

Results

Patients were followed for a minimum of 2 years. The average follow-up was 4.6 years (2–6.5 years). Two of the patients (four knees) in NG were lost to follow-up and three of the patients (6 knees) had died in the NNG leaving us with a total of 46 knees in NG and 44 knees in NNG at final follow-up. Comparison of clinical (alignment and deformity) and radiological parameters (component placement and angles) in both groups are shown in Table 1.

Alignment

The outliers for postoperative coronal plane alignment were 35.29% in the NNG and 11.76% in the NG (p-value 0.043), the difference being statistically significant. The respective numbers for postoperative sagittal plane alignment were 11.76% and 0% (p-value 0.114).

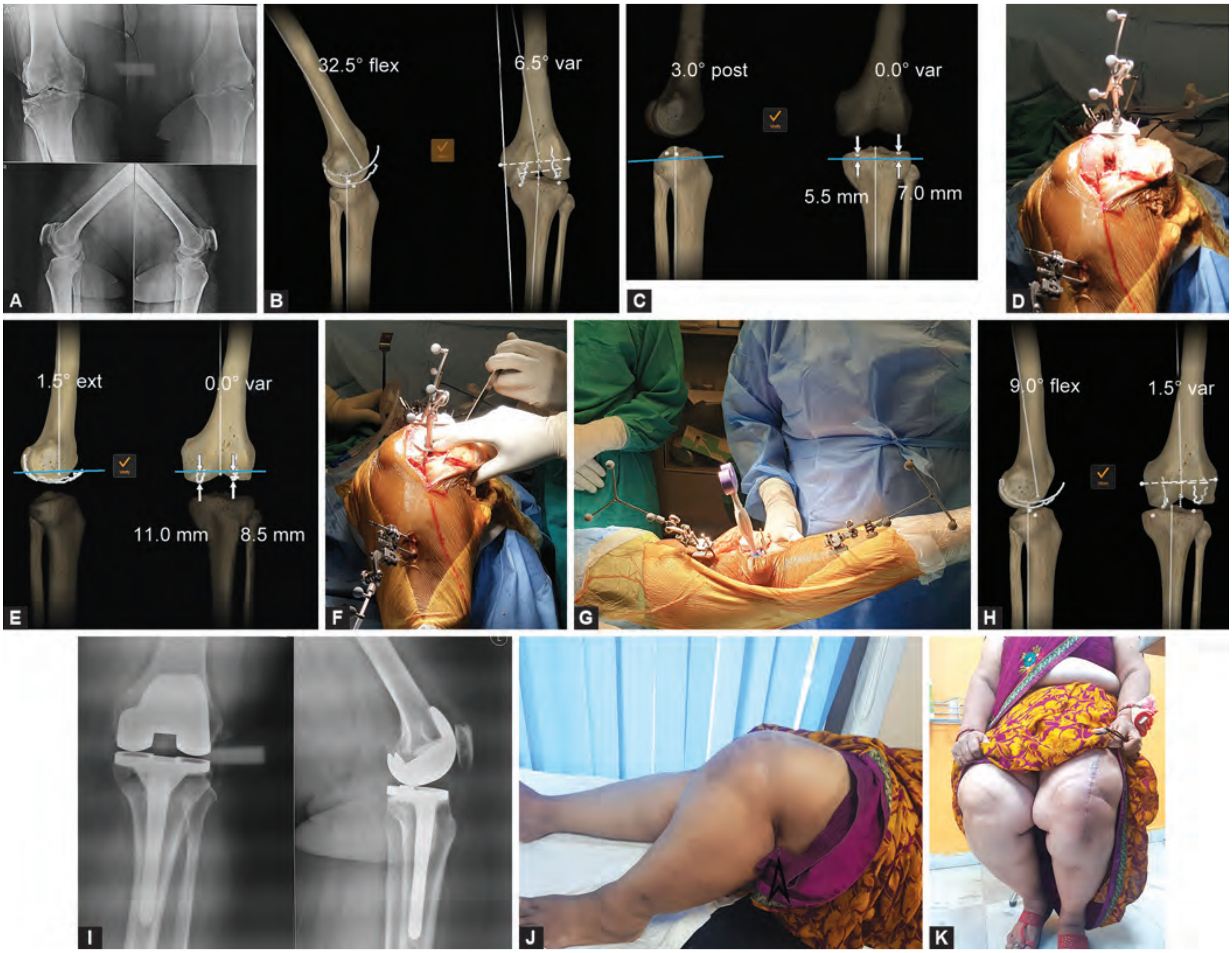
Component Placement

Outliers for alpha angle were seen in 32.35% of the patients in the NNG and 14.71% in the NG (p-value 0.086). The outliers were 11.76% and 8.82% for beta angle (p-value 1.000); 26.47% and 11.76% for gamma angle (p-value 0.217, significant); 38.24% and 23.53% for sigma angle (p-value 0.189), respectively.

Table 2 depicts the comparison of functional results between groups.

Range of Motion (ROM)

There was an improvement in the NG but no statistically significant difference in the ROM between the two study groups was seen at different time intervals, that is, preoperatively, at 2 weeks, 6 weeks,



Figs 1A to K: (A) Preoperative AP and lateral views of knee in a 52-year female patient with BMI 39.5 kg/m^2; (B) Computer showing the initial assessment of deformity as 6.5° varus and 32.5° fixed flexion deformity; (C) Navigation screen showing the conservative tibial cut; (D) Intraoperative picture showing the placement of pins for infrared reflectors in tibia through a different incision and the jig for distal femur cutting placed under navigation guidance; (E) Navigation showing the 11 m distal femoral cut to correct FFD; (F) Intraoperative verification of the navigated distal femoral cut; (G) Soft tissue balancing being performed under navigation guidance; (H) Navigation screen showing the correction of varus to 1.5° and FFD of 9° (with the final insert placed); (I) Postoperative radiographs at 2-year follow-up showing the correct implant placement with a tibial stem extender and replaced patellar button. No radiolucency seen in any zone; (J) Postoperative clinical picture showing flexion up to 110°. Arrow points to the junction where the calf fat deposits approximate at the thigh deposit and limit flexion; and (K) Postoperative clinical picture showing the arthrotomy scar and navigation pin tract scars

3 months, and 6 months postoperatively (p-value> 0.05). There was no significant difference in the gain in the range of motion in the two study groups up to 6 months postoperatively or thereafter the ROM remained the same (p-value 0.725; Table 2).

Knee Society Scoring (KSS)

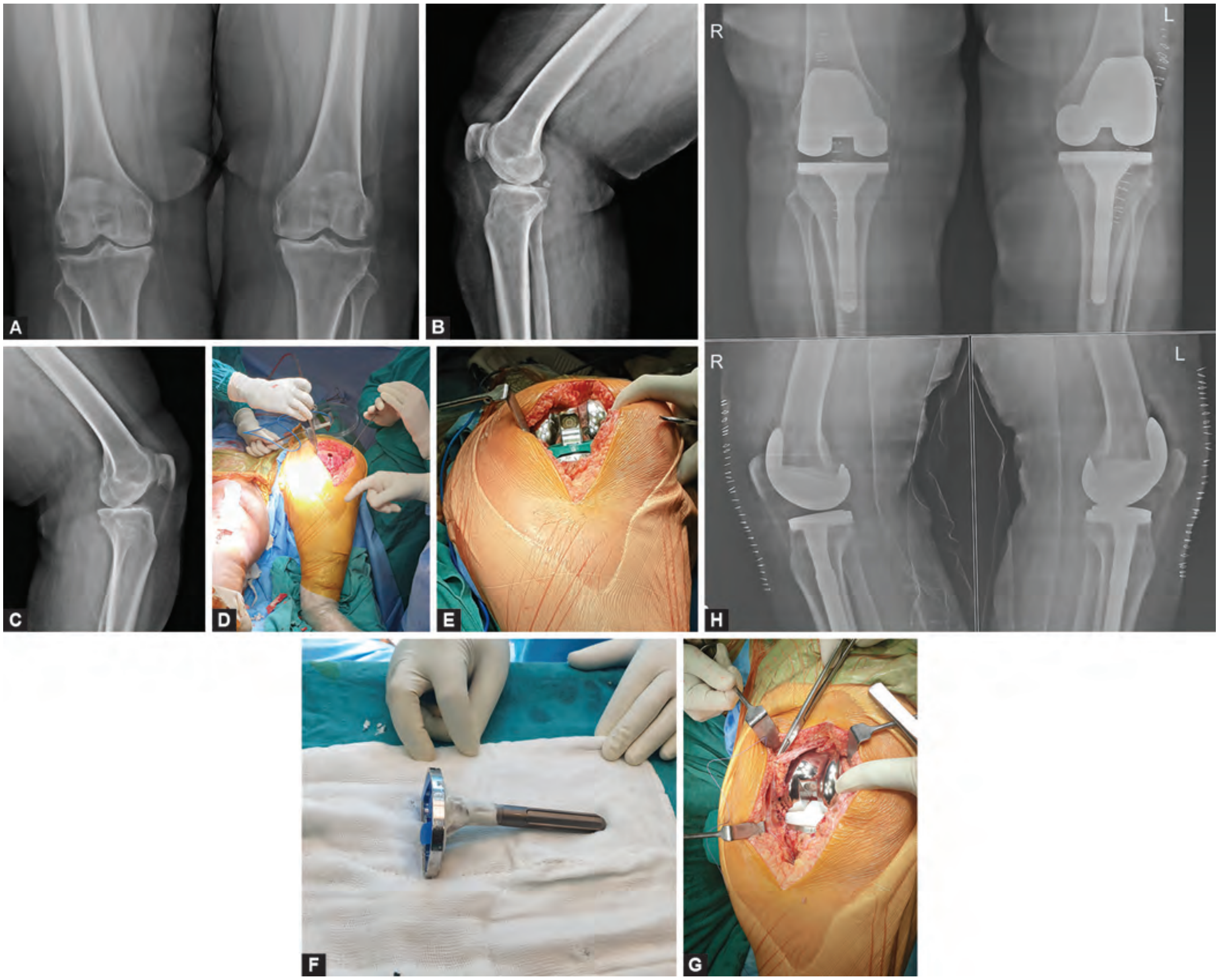
The NG group showed slightly better KSS scores than the NNG, but the difference was statistically insignificant (Table 2).

Surgery Time

The average time was 69.41 minutes for the NNG and 85.59 minutes for the NG, the difference being statistically significant; the mean duration of surgery being longer for the NG (p-value < 0.001). The fall in hemoglobin was 1.22 ± 0.36 in NG and 2.31 ± 0.24 in NNG (p = 0.210) (Table 2).

Complications

One knee in the NG group and 5 knees in the NNG developed a superficial skin infection. One patient in each group developed a deep-seated infection for which a two-stage revision was done. Deep vein thrombosis was seen in one knee in NG and 7 knees in NNG. Six knees (3 patients) in the NNG had mortality due to pulmonary embolism (PE) (proven on pulmonary CT angiography) compared to none in NG in the immediate postoperative period. These three patients had morbid obesity along with diabetes, hypertension, and low vitamin D and serum transferrin levels, although they had been cleared for surgery on preanesthetic evaluation. Anterior knee pain was reported equally in both groups irrespective of whether the patella was replaced or not. None of the patients in the groups had implant subsidence or aseptic loosening, periprosthetic fracture, or any other significant complications till the last follow-up (Table 3).



Figs 2A to H: (A to C) Preoperative AP and lateral radiographs of a 61-year obese female with BMI 40 kg/m^2; (D) Intraoperative picture showing the bilateral same sitting non-navigated TKR with distal femur first technique. Stiff fat around the knee causes much difficulty in retraction and exposure; (E) Intraoperative picture with final implant and a trial. Note the width of the thigh and the 8-in. long incision; (F) Picture of the tibial tray with stem extender. Cementation is done only till the tray-extender junction; (G) Intraoperative picture with final Depuy PFC implant with final insert; and (H) Postoperative radiographs of both knees showing the tibial stem extenders

Discussion

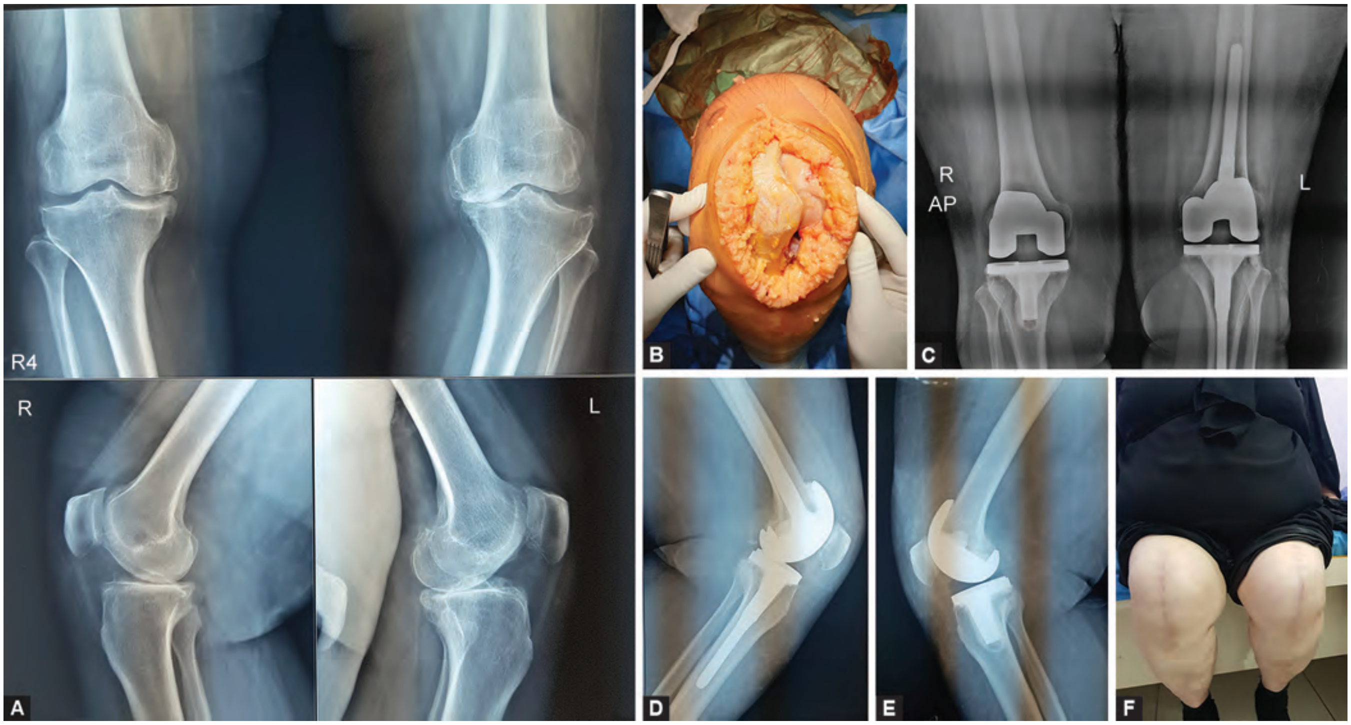
Computer-assisted TKR improves the accuracy and reproducibility over conventional techniques,[18] improves functional outcomes, and knee scores,[16] reduces blood loss,[19] and reduces morbidity and complications due to marrow embolism.[20] CAS is advantageous in obese as identification of anatomical landmarks and soft tissue balancing can be difficult when using conventional jigs.[21] Our study shows the benefit of navigation in terms of exposure, alignment, component placement, function, reduction in blood loss, reduction in PE, and time to get back to normal walking, thereby reducing morbidity.

Exposure

High-fat deposition (especially stiff) around the knee makes the exposure a tedious task in the obese as the bony landmarks are obscured, and flexion is limited due to bulky soft tissue in the thigh and calf. Navigation actually is minimally invasive, where it matters the most, as it does not violate the intramedullary canal and reduces changes of fat embolism. We lost three patients, operated without navigation, in our series to PE. There were common factors in these three patients (morbid obesity; >2 comorbidities; and poor nutritional status). We call this the "Terrible Triad of Obesity." The authors believe that this "double hit phenomenon" caused by a bilateral same-day TKR in a patient with this "Terrible Triad of Obesity" is an invitation for complications and hence bilateral surgeries should be avoided. Navigation-assisted TKR had no incidence of fatal PE in our series and so indirectly did reduce mortality in obese undergoing TKR, although a cause and association between PE and obesity cannot be derived from this outcome, nor can we conclude that navigation would invariably reduce the incidence of PE to zero in obese patients undergoing TKR.

Alignment

Malpositioning of components in obese increases the stress transmitted to the fixation interface, hence leading to premature



Figs 3A to F: (A) Preoperative AP and lateral views of the knee joint in an obese female of 58 with BMI 42 kg/m^2; (B) Intraoperative picture of the incision using the medial parapatellar approach. Note the soft mobile fat sleeve that blooms open and displaces as the joint is exposed; (C) Postoperative AP radiographs of the knee joint showing the stem extenders on the femoral and tibial side; (D) Postoperative lateral radiograph of the left knee joint at 2-year follow-up showing the stem extenders on the femoral and tibial side (hybrid cementation); (E) Postoperative lateral radiograph of the right knee joint at 2-year follow-up showing the stem extenders on the femoral and tibial side (hybrid cementation). No aseptic loosening seen; and (F) Postoperative follow-up picture showing the bilateral healed scars and flexion achieved

Table 1: Comparison of clinical and radiological parameters in both groups

Clinical and radiological parameters	*Navigated group (NG)*	*Non-navigated group (NNG)*	*p-value*
1. Varus deformity (degrees)			
Preoperative	13.62 ± 1.76	13.88 ± 1.74	
Postoperative	2.03–1.06	3.18 ± 1.74	
Improvement	11.59 ± 2.26	10.71 ± 2.07	0.109
2. Fixed flexion deformity (degrees)			
Preoperative	16.06 ± 3.72	15.91 ± 4	
Postoperative	0.79 ± 1.04	1.24 ± 1.52	
Improvement	15.26 ± 2.84	14.68 ± 2.77	0.330
3. Coronal plane alignment (degrees)			
Preoperative	166.38 ± 1.76	166.12 ± 1.74	
Postoperative alignment	177.97 ± 1.06	176.82 ± 1.24	
Improvement	11.59 ± 2.26	10.71 ± 2.07	0.109
4. Sagittal plane alignment (degrees)			
Preoperative	163.94 ± 3.72	164.09 ± 4	
Postoperative	178.76 ± 1.52	179.21 ± 1.04	
Improvement	14.68 ± 2.77	15.26 ± 2.84	0.330
5. Alpha angle (femoral component coronal alignment angle) (in degrees)	96.09 ± 2.33	96.15 ± 3.05	0.975
6. Beta angle (tibial component coronal alignment angle) (in degrees)	90.12 ± 1.61	90.21 ± 2.25	0.945
7. Gamma angle (femoral flexion angle) (in degrees)	6.32 ± 2.68	6.26 ± 1.8	0.794
8. Sigma angle (tibial slope) (in degrees)	87.79 ± 1.75	88.76 ± 2.17	0.066

Table 2: Comparison of functional results between groups

Functional results	*Navigated group (NG)*	*Non-navigated group (NNG)*	*p-value*
1. Range of motion			
Preoperative	103.35 ± 5.59	103.41 ± 4.11	
Postoperative	123.85 ± 2.43	123.38 ± 2.31	
Improvement in ROM	20.5 ± 4.56	19.97 ± 3.35	0.725
2. KSS knee score			
Preoperative	23.5 ± 12.53	24.5 ± 15.77	
Postoperative (2 yrs)	83.5 ± 4.98	83.24 ± 6.09	
Improvement in KSS	60 ± 8.61	58.74 ±12.17	0.698
3. KSS function score			
Preoperative	33.79 ± 10.44	33.85 ± 11.73	
Postoperative (2 yrs)	83.09 ± 4.59	82.79 ± 6.93	
Improvement in KSS	49.29 ± 8.18	48.94 ± 7.6	0.777
4. Fall in hemoglobin	1.22 ± 0.36	2.31 ± 0.24	0.210
5. Time to discharge (days)	Av 3.2 days	Av 5.5 days	
6. Time to unaided walking (days)	Av 12 days (U/L TKR) Av 18 days (B/L TKR)	Av 21 days (U/L TKR) Av 30 days (B/L TKR)	

Table 3: Complications and outcomes among both groups

Complications	*Navigated group (NG)*	*Non-navigated group (NNG)*	*Outcome*
Superficial wound infection	1	5 knees	Healed with dressings and local debridement
Intraoperative fractures	0	0	
Deep vein thrombosis	1	7 knees	Medical treatment
Fatal pulmonary embolism	0	6 knees (3 patients)	Death in 3 patients
Deep infection	1	1	Two-stage revision
Prosthesis loosening	0	0	
Anterior knee pain	3	3	Managed conservatively
Neurovascular complications	0	0	

wear and high failure rates.[22–25] Navigation reduces these outliers and long-term failures.

In our study, the NG showed significantly better postoperative coronal plane alignment and reduced outliers. Our results were comparable to those published in other studies that reported reduced outliers for mechanical alignment in the NG than the conventional group.[18,26–30]

We observed a greater improvement in flexion deformity in the NG (15.26°) as compared to the conventional group (14.68°), although the difference was not statistically significant (p-value = –0.330). Sharma et al. have reported better outcomes for the NG with lesser postoperative flexion deformity at 6 months for the NG (4.5°) compared to the conventional group (5.8°).[31]

Function

In our study, the mean preoperative KSS was 24.5 ± 15.77 for the NNG and 23.5 ± 12.53 for the NG which at 2 years of follow-up improved to 83.24 ± 6.09 in NNG and 83.5 ± 4.98 in the NG. This is comparable to the findings of Kim et al. and Amin et al.[32,33]

In our study, the mean postoperative ROM improved till 6 months and remained static thereafter at 2 years follow-up but was again comparable (mean ROM of 123.38 ± 2.31° for the conventional group and 123.85 ± 2.43° for the NG; p-value 0.295). Despite using high flexion components during TKR, the final ROM is less. Our observations correlate with those published by Kim et al., Hoppe et al., and Collins et al.[32,34,35]

Singh et al. in a recent study on obese patients of all categories undergoing TKA showed lower improvement in forgotten joint scores in those with higher BMI.[36] Cano et al. reported improved quality of life in the short to mid-term irrespective of the BMI.[37] Similarly, Xu et al. in a 10-year follow-up of TKA reported a clear association between low KSS, oxford knee scores, mental component scores, and obesity. At 10 years they reported similar satisfaction levels in both the obese and non-obese groups.[38]

Surgical Time

We used tourniquet time as a measure of surgical time and this was significantly longer in the NG (85.59 ± 5.7 minutes) as compared to the conventional group (69.4 ± 4.8 minutes). Our observations correlate with the study of Zhang et al.,[39] who observed an average surgical time of 58.4 minutes in the conventional group and 90.1 minutes in the computer-assisted group. Pang et al. have also reported a less tourniquet time of 116 ± 20 minutes in the conventional group compared to134 ± 18 minutes in the NG.[40]

Blood Loss

The average blood loss was lower in the NG, the difference observed was statistically insignificant (p-value 0.210). Many other studies have observed a lower average blood loss in the NG although the difference observed was statistically insignificant.[36,41,42]

Wound Healing

Substantial adipose tissue between the skin and the extensor mechanism and fat necrosis and collection in this space at the time of closure, complicates wound healing in obese. In our study, we did encounter superficial infection and wound dehiscence in 5 knees in NNG.

Revision

Chaudhry et al. in a meta-analysis comparing TKA in obese, morbid obese, and superobese concluded that the risk of septic revision was increased with progressively higher BMI but the risk of aseptic revision was similar.[43] We, however, did not encounter any aseptic loosening in our cases, although one case in each group was revised for septic loosening using a two-stage approach. Gopalakrishnan et al. have recommended the use of a tibial stem in obese patients to reduce the stress transfer to the implant cement interface.[44] We recommend the use of stem extenders in morbid obesity, osteoporosis, and those with associated bone defects.

Deep Vein Thrombosis and PE

There is a dearth of studies recommending anticoagulation protocols for preventing DVT/PE risks in obese patients. Sloan et al. in a study on TKA in obese patients found an association between obesity and increased risk of PE and not DVT. They also suggested that anticoagulation regimes reduce clinical DVT, but do not reduce fatal PE.[45] Deep vein thrombosis was less in NG (1) as compared to 7 knees in NNG (Table 3) but we had a fatal PE in 3 patients in the NNG in the immediate postoperative period as compared to none in the NG. We attribute this to the use of navigation, which indirectly reduces mortality due to PE after TKA as the medullary canal is not entered.

Bilateral same-day TKA is considered a risk factor for developing complications in morbid obese and the odd ratios of complications like infection, respiratory failure, PE, and urinary tract infection increase with increasing weight.[46] The "terrible triad of Obesity" which if present, a same-day bilateral TKR should be staged to avoid a second hit.

Our study is unique as the literature has a paucity of prospective randomized studies comparing the outcomes of TKR using navigation and without navigation in the obese. It consolidates the fact that navigation gives better outcomes in obese and also outlines the fact that obese patients are high-risk individuals for complications during and after TKR. The main drawback of our study is that only one observer had taken the readings which can lead to observer bias. Another bias (which was unavoidable) was the use of two different types of implants, with and without stem extenders. We recommend further long-term studies comparing the outcomes of TKR in morbid obese with and without stem extenders.

Conclusion

Navigation-assisted TKR in obese significantly improves the overall mechanical alignment and significantly reduces the coronal plane outliers compared to conventional TKR. Navigation marginally improves functional outcomes and range of motion, decreases morbidity by reducing blood loss and time to normalcy and better alignment reduces revisions in the near future. Navigation-assisted TKR in obese has shown a reduction in perioperative complications and it also indirectly reduces mortality by reducing the incidence of fatal PE.

However, further multicentric studies with larger sample sizes and longer duration of follow-up are advocated to see whether better alignment and function would translate into prosthesis survival in the long term.

References

1. D'Souza JC, Werner RA, Keyserling WM, et al. Analysis of the Third National Health and Nutrition Examination Survey (NHANES III) using expert ratings of job categories. Am J Ind Med 2008;51(1):37–46. DOI: 10.1002/ajim.20512.
2. Cooper C, Snow S, McAlindon TE, et al. Risk factors for the incidence and progression of radiographic knee osteoarthritis. Arthritis Rheum 2000;43(5):995–1000. DOI: 10.1002/1529-0131(200005)43:5<995::AID-ANR6>3.0.CO;2-1.
3. Srikanth VK, Fryer JL, Zhai G, et al. A meta-analysis of sex differences prevalence, incidence and severity of osteoarthritis. Osteoarthritis Cartilage 2005;13(9):769–781. DOI: 10.1016/j.joca.2005.04.014.
4. Bourne R, Mukhi S, Zhu N, et al. Role of obesity on the risk for total hip or knee arthroplasty. Clinic Orthop Relat Res 2007;465:185–188. DOI: 10.1097/BLO.0b013e3181576035.
5. Sharma L, Song J, Felson DT, et al. The role of knee alignment in disease progression and functional decline in knee osteoarthritis. JAMA 2001;286(2):188–195. DOI: 10.1001/jama.286.2.188.
6. Bates C. Fat Britain: Tackling the obesity epidemic. Available from: Daily Mail.co.uk/health.-obesity-epidemic.html.2009.
7. Misra A, Khurana L. Obesity and the metabolic syndrome in developing countries. J Clin Endocrinol Metabol 2008;93(11 supplement 1):s9–s30. DOI: 10.1210/jc.2008-1595.
8. Hart DJ, Spector TD. The relationship of obesity, fat distribution and osteoarthritis in women in the general population: The Chingford Study. J Rheumatol 1993;20(2):331–335. PMID: 8474702.
9. Felson DT, Zhang Y, Anthony JM, et al. Weight loss reduces the risk for symptomatic knee osteoarthritis in women: The Framingham study. Ann Intern Med 1992;116(7):535–539. DOI: 10.7326/0003-4819-116-7-535.
10. Bray GA. Overweight is risking fate: Definition, classification, prevalence, and risks. Ann N Y Acad Sci 1987;499(1):14–28. DOI: 10.1111/j.1749-6632.1987.tb36194.x.
11. Malnick SD, Knobler H. The medical complications of obesity. QJM 2006;99(9):565–579. DOI: 10.1093/qjmed/hcl085.
12. DeMaria EJ, Carmody BJ. Perioperative management of special populations: Obesity. Surg Clinic 2005;85(6):1283–1289. DOI: 10.1016/j.suc.2005.09.002.
13. Flegal KM. Epidemiologic aspects of overweight and obesity in the United States. Physiol Behav 2005;86(5):599–602. DOI: 10.1016/j.physbeh.2005.08.050.
14. Colditz GA. Economic costs of obesity and inactivity. Med Sci Sports Exer 1999;31(11 Suppl):S663–S667. DOI: 10.1097/00005768-199911001-00026.
15. Springer BD, Parvizi J, Austin M, et al. Workgroup of the American Association of Hip and Knee Surgeons Evidence Based Committee. Obesity and total joint arthroplasty: A literature-based review. J Arthroplasty 2013;28(5):714–721. DOI: 10.1016/j.arth.2013.02.011.
16. Choong PF, Dowsey MM, Stoney JD. Does accurate anatomical alignment result in better function and quality of life? Comparing conventional and computer-assisted total knee arthroplasty. Journal Arthroplasty 2009;24(4):560–569. DOI: 10.1016/j.arth.2008.02.018.
17. Hoffart HE, Langenstein E, Vasak N. A prospective study comparing the functional outcome of computer-assisted and conventional total knee replacement. J Bone Joint Surg Br 2012;94(2):194–199. DOI: 10.1302/0301-620X.94B2.27454.
18. Chauhan SK, Scott RG, Breidahl W, et al. Computer-assisted knee arthroplasty versus a conventional jig-based technique: A randomized, prospective trial. J Bone Joint Surg Br 2004;86(3): 372–377. DOI: 10.1302/0301-620x.86b3.14643.
19. Kalairajah Y, Simpson D, Cossey AJ, et al. Blood loss after total knee replacement: Effects of computer-assisted surgery. J Bone Joint Surg Br 2005;87(11):1480–1482. DOI: 10.1302/0301-620X.87B11.16474.
20. Lützner J, Krummenauer F, Wolf C, et al. Computer-assisted and conventional total knee replacement: A comparative, prospective, randomised study with radiological and CT evaluation. J Bone Joint Surg Br 2008;90(8):1039–1044. DOI: 10.1302/0301-620X.90B8.20553.

21. Chin PL, Yang KY, Yeo SJ, et al. Randomized control trial comparing radiographic total knee arthroplasty implant placement using computer navigation versus conventional technique. J Arthroplasty 2005;20(5):618–626. DOI: 10.1016/j.arth.2005.04.004.
22. Mont MA, Mathur SK, Krackow KA, et al. Cementless total knee arthroplasty in obese patients: A comparison with a matched control group. J Arthroplasty 1996;11(2):153–156. DOI: 10.1016/s0883-5403(05)80009-9.
23. Stern SH, Insall JN. Total knee arthroplasty in obese patients. J Bone Joint Surg Am 1990;72(9):1400–1404.PMID: 2229120.
24. Griffin FM, Scuderi GR, Insall JN, et al. Total knee arthroplasty in patients who were obese with 10 years follow-up. Clinl Orthop Relat Res 1998;356:28–33. DOI: 10.1097/00003086-199811000-00006.
25. Spicer D, Pomeroy D, Badenhausen W, et al. Body mass index as a predictor of outcome in total knee replacement. Int Orthop 2001;25(4):246–249. DOI: 10.1007/s002640100255.
26. Shinozaki T, Gotoh M, Mitsui Y, et al. Computer-assisted total knee arthroplasty: Comparisons with the conventional technique. Kurume Med J 2011;58(1):21–26. DOI: 10.2739/kurumemedj.58.21.
27. Bäthis H, Perlick L, Tingart M, et al. Alignment in total knee arthroplasty: A comparison of computer-assisted surgery with the conventional technique. J Bone Joint Surg Br 2004;86(5):682–687. DOI: 10.1302/0301-620x.86b5.14927.
28. Kamat YD, Aurakzai KM, Adhikari AR. Total knee replacement in the obese patient: Comparing computer-assisted and conventional technique. ScientificWorldJournal. 2014;2014:272838. DOI: 10.1155/2014/272838.
29. Shetty SV, Mohammed Azhruddin A, Rai D, et al. Comparison of overall component alignment and functional outcome between navigation and conventional total knee arthroplasty. Int J Orthop 2019;5(3):684–691. DOI: 10.22271/ortho.2019.v5.i3l.1614.
30. Zorman D, Etuin P, Jennart H, et al. Computer-assisted total knee arthroplasty: comparative results in a preliminary series of 72 cases. Acta orthopaedica Belgica. 2005;71(6):696. PMID:16459860.
31. Sharma DK, Rassiwala M, Neema PP. Navigation assisted total knee arthroplasty-Evaluation of correction of clinical-Radiological parameters in substantial varus deformity. Int J Orthop 2017;3(1):747–754. DOI: 10.22271/ortho.2017.v3.i1k.110.
32. Kim YH, Park JW, Kim JS. 2017 Chitranjan S. Ranawat Award: Does computer navigation in knee arthroplasty improve functional outcomes in young patients? A randomized study. Clin Orthop and Relat Res 2018;476(1):6. DOI: 10.1007/s11999.0000000000000000.
33. Amin AK, Clayton RA, Patton JT, et al. Total knee replacement in morbidly obese patients: Results of a prospective, matched study. The Journal of Bone and joint surgery. British volume. 2006;88(10):1321–1326.
34. Hoppe S, Mainzer JD, Frauchiger L, et al. More accurate component alignment in navigated total knee arthroplasty has no clinical benefit at 5-year follow-up. Acta Orthop 2012;83(6):629–633. DOI: 10.3109/17453674.2012.747923.
35. Collins JE, Donnell-Fink LA, Yang HY, et al. Effect of obesity on pain and functional recovery following total knee arthroplasty. J Bone Joint Surg Am 2017;99(21):1812. DOI: 10.2106/JBJS.17.00022.
36. Singh V, Yeroushalmi D, Lygrisse KA, et al. The influence of obesity on achievement of a 'forgotten joint' following total knee arthroplasty. Arch Orthop Trauma Surg 2021. DOI: 10.1007/s00402-021-03840-0. Online ahead of print.
37. Cano JPM, Castilla LZ, Chica J, et al. Body mass index and knee arthroplasty. J Clin Orthop Trauma 2020;11(Suppl 5):S711–S716. DOI: 10.1016/j.jcot.2020.06.015. Epub 2020 Jun 12.
38. Xu S, Chen JY, Lo NN, et al. The influence of obesity on functional outcome and quality of life after total knee arthroplasty: A ten-year follow-up study. Bone Joint J 2018;100-B(5):579–583. DOI: 10.1302/0301-620X.100B5.BJJ-2017-1263.R1.
39. Zhang GQ, Chen JY, Chai W, et al. Comparison between computer-assisted-navigation and conventional total knee arthroplasties in patients undergoing simultaneous bilateral procedures: A randomized clinical trial. JBJS 2011;93(13):1190–1196. DOI: 10.2106/JBJS.I.01778.
40. Pang CH, Chan WL, Yen CH, et al. Comparison of total knee arthroplasty using computer-assisted navigation versus conventional guiding systems: A prospective study. J Orthop Surg 2009;17(2):170–173. DOI: 10.1177/230949900901700209.
41. Gøthesen Ø, Espehaug B, Havelin LI, et al. Functional outcome and alignment in computer-assisted and conventionally operated total knee replacements: a multicentre parallel-group randomized controlled trial. Bone Joint J 2014;96(5):609–618. DOI: 10.1302/0301-620X.96B5.32516.
42. Millar NL, Deakin AH, Millar LL, et al. Blood loss following total knee replacement in the morbidly obese: Effects of computer navigation. Knee 2011;18(2):108–112. DOI: 10.1016/j.knee.2010.03.002.
43. Chaudhry H, Ponnusamy K, Somerville L, et al. Revision rates and functional outcomes among severely, morbidly, and super-obese patients following primary total knee arthroplasty: A systematic review and meta-analysis. JBJS Rev 2019;7(7):e9. DOI: 10.2106/JBJS.RVW.18.00184.
44. Gopalakrishnan A, Hedley AK, Kester MA. Magnitude of cement-device interfacial stresses with and without tibial stemming: Impact of BMI. J Knee Surg 2011;24(1):3–8. DOI: 10.1055/s-0031-1275388.
45. Sloan M, Sheth N, Lee GC. Is Obesity associated with increased risk of deep vein thrombosis or pulmonary embolism after hip and knee arthroplasty? A Large Database. Clin Orthop Relat Res 2019;477(3):523–532. DOI: 10.1097/CORR.0000000000000615.
46. Remily EA, Mohamed NS, Wilkie WA, et al. Obesity and its effect on outcomes in same-day bilateral total knee arthroplasty. Ann Transl Med 2020;8(15):936. DOI: 10.21037/atm-20-806.

RESEARCH ARTICLE

Significance of Grand Piano Sign for Rotational Alignment of Distal Femur during Total Knee Arthroplasty

Manish Shah[1], Dharan Shah[2], Ishani Patel[3], Mansi Patel[4], Neel Bhavsar[5], Dhaval Modi[6], M Ajith Kumar[7]

Received on: 25 August 2024; *Accepted on:* 10 September 2024; *Published on:* 01 October 2024

Abstract

Introduction: The cut surface of anterior cortex of the femur during a mechanically aligned total knee replacement resembles the top surface of a grand piano. It is said to be a reliable marker for correct rotational alignment of the femur.

Robotics and CT-based 3D planning have sophisticated tools for manipulating the 3D bony template of the femur. Moreover, CT-based robotics and CT-based 3D planning require CT scans for all patients undergoing surgery. Previous studies have mentioned that the grand piano sign is a good indicator of the femoral component rotation, but is the change of shape significant and predictable for all changes in alignments and rotations?

Materials and methods: A retrospective study was conducted using 200 CT scans of patients undergoing total knee replacement surgery with CT-based 3D planning. A proprietary, interactive, surgery-planning and execution software developed by the lead author (MS) (Kne3wiz by Arthro 3D LLP, http://www.arthro3d.com) was used for 3D reconstruction and planning. The system created a 3D bone model using AI segmentation.

Results: A sizable percentage (>40%) of the knees had a single peak. When the single peaks were excluded from the analysis, the ratios dropped across all alignments and with varying degrees of flexion of the femoral component. These were tested for statistical significance using ANOVA. The ratios were found to be significant with a change in flexion of more than 2°. The *p*-values for flexion in the intramedullary axis at +3 and +5 were both significant ($p = 0.003$ and $p = 0.001$, respectively).

The difference in lateral peaks was highly significant for all changes in the flexion of the femoral component; whereas a change of 3 or more degrees of flexion of the femoral component was significant for the medial peak.

Conclusion: The ratios of the lengths of medial and lateral columns of the grand piano sign vary across different alignments. The changes in ratios and measurements are more a function of the femoral component flexion than varus-valgus or rotations of the femoral component. The difference in measurements among different alignments for the length of the lateral column is highly significant. This makes it a possible tool for validation for implant position in femur with preoperative CT-based 3D planning.

Keywords: Distal femur, Grand piano, Knee arthroplasty, Rotational alignment.

Indian Journal of Arthroplasty (2024): 10.5005/ijoa-11025-0008

Introduction

The cut surface of the anterior cortex of the femur during a mechanically aligned total knee replacement resembles the top surface of a grand piano (Fig. 1). It is said to be a reliable marker for correct rotational alignment of the femur.[1] Alternative alignments other than mechanical alignment are showing good promise as well. No external rotation of the femoral component is required when using kinematic alignment.[2] Would that mean that there will be a change in the grand piano sign when the rotations are kept at zero and the femur is kept along its kinematic axis?

Recent studies have shown that the femoral anterior cortex cut varies with different alignments and has strong racial predilection.[3] There have been no Indian studies to validate the same.

Robotics and CT-based 3D planning have sophisticated tools for the manipulation of the 3D bony template of the femur. Using these systems, the cuts of the anterior cortex of the femur can be simulated on the same patient with different alignments and the ratios of the towers formed by the cut surface can be measured accurately. Moreover, CT-based robotics and CT-based 3D planning require CT scans for all patients undergoing surgery. This has led to a large pool of data which can be harnessed to further our understanding.

Evaluation of the above data can answer various questions such as How would the shape of the cut surface of the anterior cortex of the femur change with various alignments: changes in varus-valgus, flexion-extension, and external and internal rotation of femoral

[1,2]Department of Orthopaedics, Shah Hospital and SVP Hospital, Ahmedabad, Gujarat, India

[3–6]Department of Orthopaedics, Smt. NHL Municipal Medical College, Ahmedabad, Gujarat, India

[7]Department of Orthopedics, Tejasvani Hospital, Mangaluru, Karnataka, India

Corresponding Author: Manish Shah, Department of Orthopaedics, Shah Hospital and SVP Hospital, Ahmedabad, Gujarat, India, Phone: +91 9173914050, e-mail: shahhosp@gmail.com

How to cite this article: Shah M, Shah D, Patel I, *et al.* Significance of Grand Piano Sign for Rotational Alignment of Distal Femur during Total Knee Arthroplasty. Indian J Arthroplasty 2024;1(1):21–24.

Source of support: Nil

Conflict of interest: Dr M Ajith Kumar is associated as the Journal Core Committee member of this journal and this manuscript was subjected to this journal's standard review procedures, with this peer review handled independently of this editorial board member and his research group.

component? Is the change in shape significant and predictable? Previous studies have already mentioned that the grand piano sign is a good indicator of the femoral component rotation, but is the change of shape significant and predictable for all changes in alignments and rotations?

Materials and Methods

A retrospective study was carried out in a joint replacement center in Ahmedabad, Gujarat studying simulations on 200 CT scans of 200 patients undergoing total knee replacement surgery with CT-based 3D planning. The study was approved by an independent Ethics Committee. All the patients had Kellgren-Lawrence type IV osteoarthritis of the knee. All consecutive patients from August 2023 to August 2024 were included in the study. The only exclusions were patients who did not give consent for CT scans and bilateral cases.

Multislice CT scans were done on a Phillips CT scan machine (Phillips-3029A78, slice thickness 2 mm, spacing between slices 1 mm, data collection diameter 500 and KVP 120) from the hip to ankle preoperatively. Informed consent was taken for 3D CT scan. A proprietary, interactive, surgery-planning and execution software developed by the lead author (MS) (Kne3wiz by Arthro 3D LLP, http://www.arthro3d.com) was used for 3D reconstruction and planning. A 3D bone model was created by the system using AI segmentation. Various anatomical landmarks were marked on the 3D model using simultaneous images from coronal, sagittal, axial, and 3D surface rendering by one of the authors (DS). The desired implant was placed on the femur in the desired position by him and that position was marked. Using that position as a reference, the following positions were considered: (a) restricted kinematic alignment: femur in 3° valgus and 0 external rotation with three different flexions: (i) along intramedullary axis (IM), (ii) IM + 3° flexion and (iii) IM + 5° flexion; (b) mechanical alignment: femur in 0° valgus and 3 degrees external rotation with three different flexions: (i) along intramedullary axis (IM), (ii) IM + 3 degrees flexion and (iii) IM + 5° flexion; (c) varus alignment: femur in 3 degrees varus and 3° external rotation with three different flexions: (i) along intramedullary axis (IM), (ii) IM + 3° flexion and (iii) IM + 5° flexion. Thus, nine different positions were studied (Fig. 2). In each of them, the length of the medial and lateral peaks of the cut anterior surface of the femur was noted. The calculations were performed as the shortest distance to the cut edge of the anterior chamfer cut from the respective medial and lateral peaks. An image of the different measurements was taken. Three of the authors (DS, IP, MP) individually validated all the images of the 200 patients to confirm the measurements, and all the measurements were found to be in order.

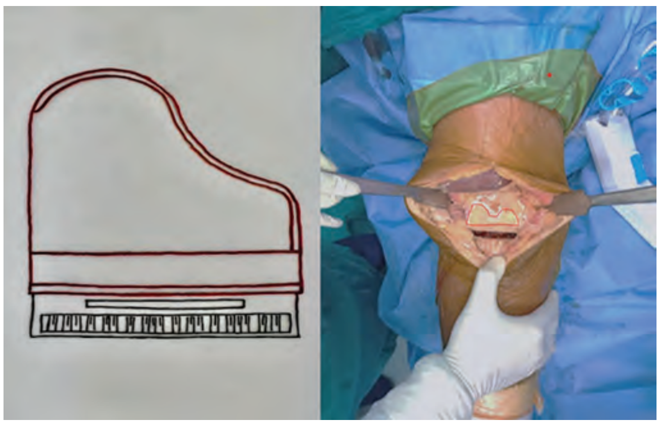


Fig. 1: The top view of a grand piano and the shape of the cut surface of the anterior cortex of the distal femur

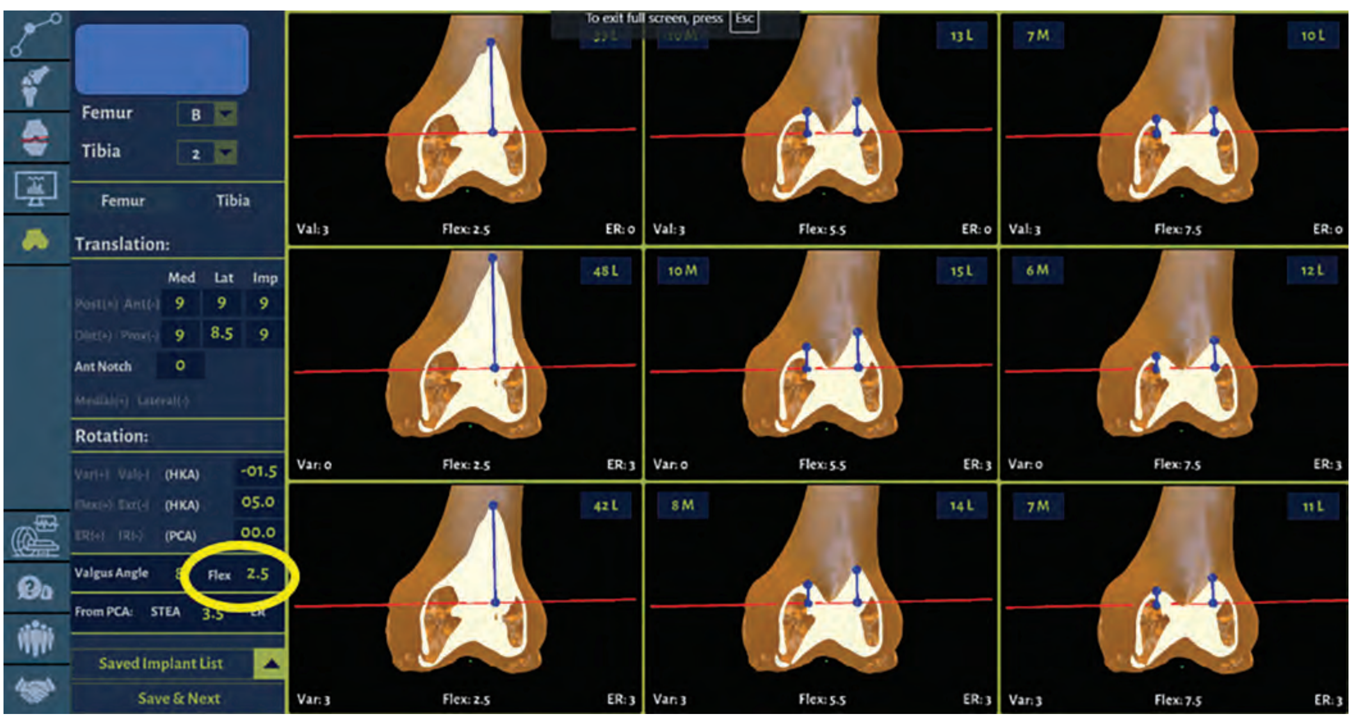


Fig. 2: Simulated cuts on the anterior surface of the distal femur. The intramedullary axis (IM axis) for this patient is in 2.5° of flexion compared with the mechanical axis. Hence, the flexion angles for the femoral component have been taken as 2.5 (IM axis), 5.5 (IM axis + 3) and 7.5 (IM axis + 5). The transverse axis represents the junction of the anterior cut with the anterior chamfer cut of the distal femur. In a 2D image it can be difficult to visualize and hence was marked elaborately by the software during the processing of the CT scan

Results

The ratio of the medial to lateral peak of the cut surface of the anterior femoral cortex was measured (Table 1). Single peaks were considered as having a ratio of 1. Statistical analysis was performed using ANOVA test with Microsoft Excel. The change in the ratios between rKinematic alignment and varus alignment was found to be statistically significant ($p = 0.001$).

A sizable percentage of the knees had a single peak (Table 2). The percentages were not significant across the various alignments but were significant for varying degrees of flexion of the femoral component. The *p*-values were less than or equal to 0.001 for all three varying degrees of flexion of the femoral component. Hence, the incidence of the single peak is a function of the degree of flexion of the femoral component.

When the single peaks were excluded from the analysis, the ratios dropped across all alignments and with varying degrees of flexion of the femoral component (Table 3). These were tested with ANOVA for statistical significance. The ratios were found to be significant with a change in flexion of more than 2°. The *p*-value for flexion in the intramedullary axis to flexion of +3 and +5 were both significant ($p = 0.003$ and $p = 0.001$, respectively).

After comparing the ratios, we compared the difference in lengths of the medial and lateral peaks in millimeters (mm) among various positions (Table 4). The change across the height of the lateral column was very significant statistically as derived by the ANOVA test. All of them had a *p*-value less than 0.0001. The change in the height of the medial column was much smaller and not statistically significant.

We also compared the difference in peaks in mm across the varying degrees of flexion of the femoral component. Here also, the difference in the lateral peaks was highly significant for all changes in flexion of the femoral component; whereas change of 3 or more degrees of flexion of the femoral component was significant for the medial peak.

Discussion

The grand piano sign for the cut anterior surface of the distal femur with its medial and lateral peaks has shown fairly similar results across Southeast Asia. Table 5 presents the different studies published in the last 20 years from Southeast Asia with different modalities like CT and MRI. All of them have a ratio of the lengths of the medial and lateral peaks of the grand piano around 0.6.

The difference between alignments also is similar across the different South Asian countries as given in the table.

In our study, at least one in five knees (~21%) had a single peak. This was the same across all alignments but was a significant function of the flexion of the component. When the cut was taken flush to the cortex, it was a single peak in close to half the knees. But that dropped to almost 1 in 10 when the femoral component was kept in slight flexion to the intramedullary axis. This finding has not been reported in any of the previous studies. Moreover, whenever there was a single peak, the ratio of the medial and lateral columns is considered as 1. This confounds the results, though the results matched exactly with those published in other works in different

Table 1: Ratio of medial and lateral peaks

Alignment	*IM*	*IM + 3*	*IM + 5*	*Avg.*	*Freq. of single peaks (%)*
rKinematic alignment	0.64	0.61	0.63	0.628	21
Mechanical alignment	0.61	0.54	0.57	0.575	21
Varus alignment	0.59	0.54	0.57	0.567	20.7

Table 2: Percentage of single peaks

Alignment	*IM*	*IM + 3*	*IM + 5*	*Avg.*
rKinematic alignment	42.5	8	12.5	21
Mechanical alignment	44	9.5	14	21
Varus alignment	42	9.5	13.5	20.7

Table 3: Ratio of medial and lateral peaks

Excluding single peaks	*IM*	*IM + 3*	*IM + 5*	*Avg.*
rKinematic alignment	0.38	0.58	0.57	0.53
Mechanical alignment	0.31	0.49	0.50	0.45
Varus alignment	0.31	0.50	0.51	0.46

Table 4: Alignment and difference in peaks in mm

							p-value	
	IM		*IM + 3*		*IM + 5*		*ANOVA test*	
Between alignments	*Med*	*Lat*	*Med*	*Lat*	*Med*	*Lat*	*Med*	*Lat*
rKine v/s Mech	–0.7	6.01	–0.8	2.63	–0.4	1.37	0.03	<0.0001
rKine v/s Varus	–0.7	4.07	–0.7	–21.2	–2.74	–25.8	0.01	<0.0001
Mech v/s Varus	–0.1	–1.9	–0.1	–0.8	0	–0.6	0.92	<0.0001

Table 5: Different regional studies

No.	*Year*	*Author*	*Country*	*Inv*	*N*	*Ratio*
1	2006	Cui WQ et al.[4]	Korea	CT	50	0.6
2	2018	Ohmori et al.[5]	Japan	CT	50	0.62–0.67
3	2018	Kim et al.[6]	Korea	CT	60	0.73–0.76 for KA, 0.57–0.63 for MA
4	2021	Cho BW et al.[7]	Korea	MRI	267	0.63
5	2023	Yasuhiko Kokubu et al.[8]	Japan	CT	120	0.57–0.64 for KA, 0.53–0.57 for MA
6	2023	Kim et al.[9]	Korea	CT	234	0.61
7	2024	Present study	India	CT	200	0.61–0.64 for rKA, 0.54–0.61 for MA

Table 6: Flexion and difference in cuts in mm

Femoral component flexion angle	rKinematic		Mechanical		Varus		p-value ANOVA test	
	Med	Lat	Med	Lat	Med	Lat	Med	Lat
Between IM and IM + 3	4.17	23	5.77	26.4	5.43	25.3	0.0001	0.0004
Between IM + 3 and IM + 5	2.49	3.53	2.12	4.78	2.08	4.58	0.04	<0.0001
Between IM and IM + 5	5.63	26.5	7.02	31.2	7.16	29.8	0.0066	<0.0001

countries. When the single peaks are removed from the analysis, the results change. Also, this is the first study to report this change in values. Though, all the previous studies have had similar ratios of single peaks.

The change in the ratios between rKinematic alignment and varus alignment was found to be statistically significant ($p = 0.001$). But the range is fairly wide. The range for ratios of rkinematic alignment is 0.08–2.2 while the range for varus alignment is 0.01–2.44. Due to this huge overlap of values, the use of direct measurement during surgery would not be very reliable to predict any alignment or the degree of flexion of the femoral component.

Ours is the first study to measure the difference in millimeters for the length of the peaks of the grand piano sign. The difference in millimeters across various alignments and varying degrees of flexion of the femoral component has been found to be significant. But, more importantly, a minimum difference of 2 mm is noted across all measurements for every individual knee. Hence, they would be easily reproducible on the table, if the primary measurement for that knee is known preoperatively. There is a linear and predictable, symmetrical progression of decrease in lengths when flexion of the femoral component is increased (Table 6). There is an exponential progression with a decrease in medial column length and an increase in lateral column length as rotation of the femoral component is increased (Table 4). Varus-valgus orientation has a small effect on the change in lengths of columns. Yasuhiko Kokubu et al.[8] also had similar results for change in varus- valgus alignments. They showed that the variations are smaller in valgus knees but the grand piano sign does have the same ratios.

In the era of CT-based planning, this can be a vital measurement for cross-check across alignments and degrees of flexion. The length of the peak from the top of the anterior chamfer cut to the top of the peak is devoid of cartilage and other soft tissues, making it a reliable measure for preoperative CT scan assessment. Probably, it would work equally well as an intraoperative measurement, but it was beyond the scope of the present study. Using the grand piano sign and its measurements in an individual patient can help a surgeon move from CT-based planning to execution with a cross-check based on the different lengths of the peaks of the grand piano sign. It would ensure accuracy without the need for capital-intensive investments like navigation or robotics. Further studies to document this capability would be warranted.

The limitation of this study was that it has been a retrospective study to see the changes in the grand piano sign. A prospective study is needed to see whether the calculated measurements on the CT reflect those which are found on the table. Also, a postoperative CT may be necessary to check the final orientation of the implant to confirm whether it co-relates with the preoperative as well as the operative measurements. However, this study opens up the possibility of using these measurements as a validation tool for implant position in the femur.

Maybe, in the era of 3D planning, the melody of the grand piano will play again.

Conclusion

The grand piano sign in Indian patients has similar ratios to what has been documented across various other studies in Southeast Asia. The ratios of the lengths of medial and lateral columns are different for different alignments. The change in ratios and measurements is more of a function of the femoral component flexion than varus-valgus or rotations of the femoral component. The difference in measurements among different alignments for the length of the lateral column is highly significant. This makes it a possible tool for validation for implant position in femur with preoperative CT-based 3D planning. Further studies are warranted.

Orcid

Manish Shah https://orcid.org/0000-0002-8207-1237
Ishani Patel https://orcid.org/0000-0001-7897-8963
Mansi Patel https://orcid.org/0009-0000-5225-1387
Dhaval Modi https://orcid.org/0009-0004-6053-0908

References

1. Griffin FM, Insall JN, Scuderi GR. The posterior condylar angle in osteoarthritic knees. J Arthroplasty. 1998;13(7):812–815. DOI: 10.1016/s0883-5403(98)90036-5.
2. Koh DTS, Woo YL, Yew AKS, et al. Kinematic aligned femoral rotation leads to greater patella tilt but similar clinical outcomes when compared to traditional femoral component rotation in total knee arthroplasty. A propensity score matched study. Knee Surg Sports Traumatol Arthrosc 2021;29(4):1059–1066. DOI: 10.1007/s00167-020-06081-7.
3. Mahfouz MR, ElHak Abdel Fatah E, Bowers L, et al. A new method for calculating femoral anterior cortex point location and its effect on component sizing and placement. Clin Orthop Relat Res 2015;473(1):126–132. DOI: 10.1007/s11999-014-3930-1.
4. Cui WQ, Won YY, Baek MH, et al. Variations of the 'grand-piano sign' during total knee replacement. A computer-simulation study. J Bone Joint Surg Br 2006;88(11):1441–1447. DOI: 10.1302/0301-620X.88B11.17648.
5. Ohmori T, Kabata T, Kajino Y, et al. Usefulness of the "grand-piano sign" for determining femoral rotational alignment in total knee arthroplasty. Knee 2018;25(1):15–24. DOI: 10.1016/j.knee.2017.11.008.
6. Kim JT, Han J, Shen QH, et al. Morphological patterns of anterior femoral condylar resection in kinematically and mechanically aligned total knee arthroplasty. J Arthroplasty 2018;33(8):2506–2511. DOI: 10.1016/j.arth.2018.03.063.
7. Cho BW, Nam JH, Koh YG, et al. Gender-based quantitative analysis of the grand piano sign in mechanically aligned total knee arthroplasty in Asians. J Clin Med 2021;10(9):1969. DOI: 10.3390/jcm10091969.
8. Kokubu Y, Kawahara S, Hamai S, et al. "Grand-piano sign" as a femoral rotational indicator in both varus and valgus knees: a simulation study of anterior resection surface in total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2023;31(8):3259–3267. DOI: 10.1007/s00167-023-07365-4.
9. Kim SH, Park YB, Baek SH, et al. "Boot Sign" of anterior femoral condylar resectional shape during total knee arthroplasty is more frequent in Asian Patients. J Pers Med 2023;13(12):1684. DOI: 10.3390/jpm13121684.

REVIEW ARTICLE

Augmented Reality in Total Knee Replacement (TKR): A Narrative Review

Amit K Yadav[1], Aatif Mahmood[2], Nikhil Shah[3]

Received on: 03 September 2024; *Accepted on:* 23 September 2024; *Published on:* 01 October 2024

Abstract

Total knee replacement (TKR) is a surgical procedure to alleviate pain and restore function in patients with severe knee arthritis or other debilitating knee conditions. The success of TKR is influenced by various factors, such as component position, alignment, implant size, soft tissue balance, and the surgeon's technique, expertise, and experience. Computer-aided techniques like navigation and robotics have been increasingly adopted to enhance precision. Augmented reality (AR), which integrates real-world information with virtual data, is emerging to enhance surgeons' capabilities by providing augmented medical information, leveraging deep learning and artificial intelligence. Augmented reality is believed to increase precision and improve patient outcomes. The article discusses AR technology's potential benefits, applications, and challenges in TKR. While AR shows promise and could revolutionize orthopedic surgery by improving the understanding of 3D anatomical relationships and precise implant positioning, it is still not widely used. Future advancements are necessary to address existing challenges, and well-designed randomized trials with standardized outcomes are needed to compare AR technology with current navigational systems in knee replacements.

Keywords: Augmented reality, Implant, Total knee arthroplasty.

Indian Journal of Arthroplasty (2024): 10.5005/ijoa-11025-0004

Introduction

Total knee replacement (TKR) is a common surgical procedure that alleviates pain and restores function in patients with severe knee arthritis.[1] The outcome of a knee replacement depends on multiple factors, including component position, alignment, implant size and adequate soft tissue balance. The surgeon's technique, expertise, and experience all play a role in how precisely the implant is positioned. There has also been a rise in incorporating computer-aided techniques such as navigation and robotics to improve accuracy.[2–4]

Augmented reality (AR) means real-world information augmented with virtual information. It enhances surgeons' capabilities by providing augmented medical information.[5] Augmented reality technology involves deep learning and artificial intelligence. Proponents of AR believe that it increases precision and improves patient outcomes.

This article will cover the use of AR technology in total knee replacement, including its benefits, applications, and challenges.

AR in Knee Replacement

The surgeon acquires 2D information through a normal radiograph or CT scan and maps it to 3D anatomy. Augmented reality provides surgeons with real-time, interactive visual guidance during the procedure by overlaying digital information onto the real world. Augmented reality helps surgeons in preoperative planning and implant orientation. Augmented reality has been used in different types of orthopedic surgery like vertebroplasty, intramedullary nail, complex pelvis and acetabulum fracture, sacroiliac screw, high tibial osteotomy, tumor surgery, spine surgery and acetabular cup placement in hip replacement.[6–9]

Since 2000, researchers and companies have been investigating the application of AR in TKR surgery; however, its maturity has advanced considerably in the past decade. Next AR TKA, which received federal drug authority (FDA) clearance in 2020, employs a preoperative CT scan of the patient's knee for surgical planning. During the procedure, augmented reality glasses enable the orthopedic surgeon to see the knee's structures and monitor progress in real-time directly in the surgical field, eliminating the need to glance at a computer screen. In 2022, Dr Vigdorchik performed the first AR knee replacement at the Hospital for Special Surgery in the USA.

In TKR, AR systems utilize preoperative imaging data (CT scans) to create a virtual 3D model that aids in assessing damaged cartilage and planning bony cuts for precise implant placement. During the process, sensors affixed to the leg offer data on ligament tension, and the surgeon uses AR glasses to view the knee in three dimensions.

Several AR technologies are currently being developed and implemented in TKR procedures:

Head-mounted Displays (HMDs)

Augmented reality glasses or AR headsets that surgeons wear show relevant digital info in front. As a result, these head rigs can provide real-time guidance and visualization that allow for accurate tracking during all stages of the procedure.

[1–3]Department of Orthopedics, Wrightington Hospital, Wigan, United Kingdom

Corresponding Author: Amit K Yadav, Department of Orthopedics, Wrightington Hospital, Wigan, United Kingdom, Phone: +07587397386, e-mail: amit_aur09@yahoo.com

How to cite this article: Yadav AK, Mahmood A, Shah N. Augmented Reality in Total Knee Replacement (TKR): A Narrative Review. Indian J Arthroplasty 2024;1(1):25–28.

Source of support: Nil

Conflict of interest: None

AR-integrated Surgical Robots

Augmented reality systems with robotics help surgeons achieve accurate implant placement. These systems combine the precision of robotics with the intuitive guidance of AR, enhancing overall surgical accuracy.

Mobile Device or Tablet

Augmented reality systems use smartphones or iPads to project augmented images onto the patient's knee. Operating surgeons can change the device's orientation to view different angles and obtain information about the procedure.

Potential Advantages of AR in TKR

Improved Precision and Accuracy

Augmented reality offers surgeons intricate, three-dimensional visualizations of the patient's knee anatomy, aiding in the precise alignment and placement of implants. This accuracy helps mitigate the risk of malalignment, a frequent cause of implant failure and subsequent revision surgery.[10]

Castellarin G et al. reported on the outcomes of 76 total knee replacement surgeries using AR, comparing preplanned and achieved varus and slope cuts. They discovered that the varus and slope angles achieved with AR closely matched the preplanned angles, with less than 1% error, which was not statistically significant. Additionally, there was a minimal delay in the overall surgery duration when using AR.[11]

The NextAR TKA system measures the strain on the medial and lateral collateral ligaments across the full range of motion, rather than focusing only on the mediolateral gap. The length of the collateral ligament is measured with the knee in full extension before any bone cuts are made. This measurement is a reference for the remainder of the procedure and is used to accurately restore the ligament tension using AR technology. It also ensures the tibial component reaches the desired rotation.[12]

Image-based AR technology achieves accurate alignment in the sagittal and coronal planes compared to imageless technology, which lacks precision in the tibia's sagittal alignment.[13] The pilot study of Iacono V et al. concluded that the AR system is effective for knee alignment and could be a viable alternative to other technologies, such as navigation. However, further research is needed to determine its cost-effectiveness.[14]

Cutting errors can still occur even when using computer-assisted surgery (other than AR). However, these errors can be minimized with augmented reality, which provides a precise alignment assessment.[15] In total knee arthroplasty, an augmented reality-based system ensures precise rotational, coronal, and sagittal alignment for both tibial and distal femur resections, offering greater accuracy than conventional knee replacement methods.[16,17] Unlike navigation and robotics, the key advantage of augmented reality is that it allows surgeons to maintain their focus on the surgical field without looking away.

Improved Surgical Outcomes

Augmented reality is supposed to improve the precision of implant position, so patients may potentially experience faster recovery times and better function. Shim GY et al. conducted a study comparing AR-based rehabilitation to conventional rehabilitation. They divided 56 participants into two groups, each undergoing 12 weeks of rehabilitation. The traditional rehabilitation group performed home-based exercises, while the AR group received exercise instructions displayed on a monitor with real-time feedback. The study concluded that AR-based rehabilitation leads to better functional outcomes, pain relief and quality of life, making it a superior alternative to conventional rehabilitation.[18] A systematic review by Wang indicated that technology-assisted rehabilitation leads to a modest improvement in pain in total knee arthroplasty. However, the review primarily focused on telerehabilitation and did not include AR.[19]

Enhanced Training and Education

Augmented reality is essential for surgical education and training. It allows trainee surgeons to rehearse intricate procedures within a simulated setting, enabling them to build confidence and acquire hands-on experience before performing real surgeries. Augmented reality-guided simulations effectively connect theoretical knowledge with practical skills.

Mastering surgical skills and complex procedures is a lengthy process, but AR aids trainees in understanding 3D anatomy and instrumentation. This technology offers an interactive learning experience and improves training in knee arthroplasty.

Reduced Surgical Time

Augmented reality provides immediate feedback, avoids repeated adjustments, and potentially reduces the duration of the procedure. This minimizes the anesthesia time and increases the operation room utilization time. Reducing surgical time has the benefit of minimizing both the duration of anesthesia and its risks. Shorter surgeries also lead to less blood loss, a lower risk of infection, and improved operating room utilization.[20]

Reduce Intraoperative and Postoperative Malalignment

The hypothesis is that AR will help achieve precision of implant position, reducing the chance of competent malalignment, especially rotation of components, and postoperatively improving range of motion and function. However, it is a new tool on the market and needs further research.

Challenges

Although AR looks promising for improving the accuracy of implant positioning in TKR, there are several challenges to overcome:

- Technical limitations: Devices used in AR, such as HMDs and smart glasses, may have limitations in battery life, field of view and resolution. In addition, it can be challenging to integrate AR software with current imaging systems for CT and MRI scans. Accurately overlaying digital data in the surgical field is crucial.[21] The processing of this AR data requires significant computing power, a lack of which can cause latency and disrupt the surgical workflow, leading to a lack of accuracy and complications. Augmented reality relies on markers attached to the patient or the operating table; these must remain stable throughout the procedure for successful surgery. Hardware or software failures can be challenging to address intraoperatively, and backup systems must be in place if the technology fails.
- Surgeon comfort: Extended use of AR devices can cause postural and visual fatigue.[22] Augmented reality generates images at a fixed focal length, resulting in a difference between focus and divergence points.[22–25] This is known as vergence-accommodation conflict, causing eye fatigue and headaches.[22] This can initially disrupt established practice, leading to longer operating times. In addition, some studies have reported that using HMDs might cause motion sickness.[26]

- Expensive: The cost-to-benefit ratio is the main limitation for many healthcare systems.[24] This is further compounded by ongoing maintenance and updates. However, AR proponents argue it is cost-effective compared to robotic and navigational systems.[27] The FDA-approved ViSAR employs Microsoft HoloLens 2 (HMD) for guidance during spine surgery, which costs $3500 compared to $1.36 million for robotic systems.[12,28]
- Ethical concern: Concerns exist regarding collecting and processing sensitive patient data using AR systems.[25] Lack of privacy has been a recent concern with AR; therefore, complying with data protection regulations is crucial. Also, if there is a breach of data, it is a dilemma of who will be responsible hospital, the surgeon, or the company.

  If the AR system does not function well, it may affect patient outcomes and safety. Augmented reality surgeons also need proper training to avoid errors and achieve good outcomes. There should be ongoing research and monitoring to assess the long-term effects of AR on patient outcomes and overall healthcare quality. Ethical concerns may arise if the technology is used before sufficient evidence supports its long-term benefits.
- Compatibility: Healthcare databases often need to be more compatible between hospitals. Augmented reality performance depends on data, and regulatory authorities must invest in data infrastructure, such as the standardization of electronic health records.[29] Unstructured data can lead to misleading results.[30]
- Integration with clinical workflow: Current systems require complex patient–AR system registration. This relies on external navigation systems that can pose problems with line-of-sight, thus restricting the surgical team's freedom of movement.[24] A significant level of user engagement is needed to overcome the ill-posed registration challenge, which can disrupt workflow and reduce theater efficiency.[24] It is crucial that AR systems seamlessly integrate without causing delays or additional steps.

Outcomes

Bennett KM et al. used augmented reality on 18 patients for total knee arthroplasty, demonstrating accurate coronal alignment with a low malposition rate, though some sagittal alignment outliers were observed. The study found a learning curve, as operative time decreased significantly with experience, while accuracy remained consistent throughout.[31] Augmented reality was evaluated as a surgical tool in total knee arthroplasty, focusing on the accuracy of tibial cuts and surgery duration. In a study of 76 patients, AR-guided tibial cuts with minimal time were added to the procedure and showed mean differences of 0.59° for varus angles and 0.70° for slope angles. Most cases had differences of less than 1°, demonstrating excellent accuracy.[11]

Future Directions

Augmented reality technology is on the rise and could transform the future of orthopedic surgery, and although it has shown potential, it is still far from widespread use. It is a useful tool to aid in our understanding of 3D anatomic relationships and the location of deeper structures.[9] Future developments will likely improve precise implant positioning, particularly in patients with advanced arthritis, who want to achieve a well-balanced knee. Compared to the navigation systems used today, AR may prove to be a better alternative as it is more portable. Future developments in AR must overcome the existing challenges for us to adopt this in our daily clinical practice. Well-designed randomized trials with standardized outcomes are needed to compare AR technology with conventional or current navigational knee replacements.

References

1. Shan L, Shan B, Suzuki A, et al. Intermediate and long-term quality of life after total knee replacement: A systematic review and meta-analysis. J Bone Joint Surg Am 2015;97(2):156–168. DOI: 10.2106/JBJS.M.00372.
2. Hoffart HE, Langenstein E, Vasak N. A prospective study comparing the functional outcome of computer-assisted and conventional total knee replacement. J Bone Joint Surg Br 2012;94(2):194–199. DOI: 10.1302/0301-620X.94B2.27454.
3. Anderson KC, Buehler KC, Markel DC. Computer assisted navigation in total knee arthroplasty. J Arthroplasty 2005;20(7 Suppl 3):132–138. DOI: 10.1016/j.arth.2005.05.009.
4. Bäthis H, Perlick L, Tingart M, et al. Alignment in total knee arthroplasty: A comparison of computer-assisted surgery with the conventional technique. J Bone Joint Surg Br 2004;86(5):682–687. DOI: 10.1302/0301-620x.86b5.14927.
5. Wellner P, Mackay W, Gold R. Back to the real world. Commun ACM 1993;36(7):24–26. DOI: 10.1145/159544.159555.
6. Andress S, Johnson A, Unberath M, et al. On-the-fly augmented reality for orthopedic surgery using a multimodal fiducial. J Med Imag 2018;5(2):021209. DOI: 10.1117/1.JMI.5.2.021209.
7. Wu JR, Wang ML, Liu KC, et al. Real-time advanced spinal surgery via visible patient model and augmented reality system. Comput Methods Programs Biomed 2014;113(3):869–881. DOI: 10.1016/j.cmpb.2013.12.021.
8. Cho HS, Park MS, Gupta S, et al. Can augmented reality be helpful in pelvic bone cancer surgery? An in vitro study. Clin Orthop Relat Res 2018;476(9):1719–1725. DOI: 10.1007/s11999.0000000000000233.
9. Fallavollita P, Brand A, Wang L, et al. An augmented reality C-arm for intraoperative assessment of the mechanical axis: A preclinical study. Int J Comput Assist Radiol Surg 2016;11(11):2111–2117. DOI: 10.1007/s11548-016-1426-z.
10. Berend M. Consequences of malalignment in total knee arthroplasty: Few if any-opposes. Seminars in Arthroplasty 2010;21(2):99–101. DOI: 10.1053/j.sart.2009.12.009.
11. Castellarin G, Bori E, Barbieux E, et al. Is total knee arthroplasty surgical performance enhanced using augmented reality? A single-center study on 76 consecutive patients. J Arthroplasty 2024;39(2):332–335. DOI: 10.1016/j.arth.2023.08.013.
12. Fucentese SF, Koch PP. A novel augmented reality-based surgical guidance system for total knee arthroplasty. Arch Orthop Trauma Surg 2021;141(12):2227–2233. DOI: 10.1007/s00402-021-04204-4.
13. Hong HT, Koh YG, Cho BW, et al. An image-based augmented reality system for achieving accurate bone resection in total knee arthroplasty. Cureus 2024;16(4):e58281. DOI: 10.7759/cureus.58281.
14. Iacono V, Farinelli L, Natali S, et al. The use of augmented reality for limb and component alignment in total knee arthroplasty: Systematic review of the literature and clinical pilot study. J Exp Orthop 2021;8(1):52. DOI: 10.1186/s40634-021-00374-7.
15. Bäthis H, Perlick L, Tingart M, et al. Intraoperative cutting errors in total knee arthroplasty. Arch Orthop Trauma Surg 2005;125(1):16–20. DOI: 10.1007/s00402-004-0759-1.
16. Tsukada S, Ogawa H, Nishino M, et al. Augmented reality-assisted femoral bone resection in total knee arthroplasty. JB JS Open Access 2021;6(3):e21.00001. DOI: 10.2106/JBJS.OA.21.00001.
17. Tsukada S, Ogawa H, Nishino M, et al. Augmented reality-based navigation system applied to tibial bone resection in total knee arthroplasty. J Exp Orthop 2019;6(1):44. DOI: 10.1186/s40634-019-0212-6.
18. Shim GY, Kim EH, Lee SJ, et al. Postoperative rehabilitation using a digital healthcare system in patients with total knee arthroplasty: A randomized controlled trial. Arch Orthop Trauma Surg 2023;143(10):6361–6370. DOI: 10.1007/s00402-023-04894-y.

19. Wang X, Hunter DJ, Vesentini G, et al. Technology-assisted rehabilitation following total knee or hip replacement for people with osteoarthritis: A systematic review and meta-analysis. BMC Musculoskelet Disord 2019;20(1):506. DOI: 10.1186/s12891-019-2900-x.
20. Dobson PF, Reed MR. Prevention of infection in primary THA and TKA. EFORT Open Rev 2020;5(10):604–613. DOI: 10.1302/2058-5241.5.200004.
21. Blum T, Kleeberger V, Bichlmeier C, et al. Mirracle: An augmented reality magic mirror system for anatomy education. In: 2012 IEEE Virtual Reality (VR). Costa Mesa;2012:115–116. Available from: http://ieeexplore.ieee.org/document/6180909/.
22. Condino S, Turini G, Parchi PD, et al. How to build a patient-specific hybrid simulator for orthopaedic open surgery: Benefits and limits of mixed-reality using the microsoft hololens. Journal of Healthcare Engineering 2018;2018:1–12. DOI: 10.1155/2018/5435097.
23. Lin YH, Huang TW, Huang HH, et al. Liquid crystal lens set in augmented reality systems and virtual reality systems for rapidly varifocal images and vision correction. Opt Express 2022;30(13):22768–22778. DOI: 10.1364/OE.461378.
24. Matthews JH, Shields JS. The clinical application of augmented reality in orthopaedics: Where do we stand? Curr Rev Musculoskelet Med 2021;14(5):316–319. DOI: 10.1007/s12178-021-09713-8.
25. Mah ET. Metaverse, AR, machine learning & AI in Orthopaedics? J Orthop Surg (Hong Kong) 2023;31(1):102255362311653. DOI: 10.1177/10225536231165362.
26. Yoon JW, Chen RE, Han PK, et al. Technical feasibility and safety of an intraoperative head-up display device during spine instrumentation. Int J Med Robot 2017;13(3):e1770. DOI: 10.1002/rcs.1770.
27. Canton SP, Austin CN, Steuer F, et al. Feasibility and usability of augmented reality technology in the orthopaedic operating room. Curr Rev Musculoskelet Med 2024;17(5):117–128. DOI: 10.1007/s12178-024-09888-w.
28. Dennler C, Bauer DE, Scheibler AG, et al. Augmented reality in the operating room: A clinical feasibility study. BMC Musculoskelet Disord 2021;22(1):451. DOI: 10.1186/s12891-021-04339-w.
29. Choudhury A, Asan O. Role of artificial intelligence in patient safety outcomes: Systematic literature review. JMIR Med Inform 2020;8(7):e18599. DOI: 10.2196/18599.
30. Davatzikos C. Machine learning in neuroimaging: Progress and challenges. NeuroImage 2019;197:652–656. DOI: 10.1016/j.neuroimage.2018.10.003.
31. Bennett KM, Griffith A, Sasanelli F, et al. Augmented reality navigation can achieve accurate coronal component alignment during total knee arthroplasty. Cureus 2023;15(2):e34607. DOI: 10.7759/cureus.34607.

CASE SERIES

Late Spontaneous Dissociation of Bipolar Hemiarthroplasty Components: A Case Series and Review of Literature

Amrit Goyal[1], Yashvardhan Sharma[2], Mayur Gupta[3], Ankit Kapoor[4], Jawahar Panjwani[5], Kartik Pruthi[6]

Received on: 02 August 2024; *Accepted on:* 30 August 2024; *Published on:* 01 October 2024

Abstract

Background: The incidence of femoral neck fractures is increasing among the geriatric population due to longer life expectancy, necessitating effective management strategies. Bipolar hemiarthroplasty is commonly used for intracapsular fractures in elderly or neglected cases, despite well-documented complications such as infection, implant loosening, and dislocation.

Methods: This case series presents four patients with an unusual complication: Late spontaneous dissociation of bipolar hemiarthroplasty components. The inner articulating component separated from the outer implant after 7–14 years postsurgery, causing compromised hip function and requiring revision surgery. Clinical presentations, radiographic findings, and management strategies, including conversion to total hip arthroplasty (THA) are detailed.

Results: Radiographic evaluations confirmed dissociation of the bipolar components in all cases, prompting surgical intervention. Postoperative recoveries were generally uneventful, with patients experiencing significant pain relief and improved mobility.

Conclusion: Late spontaneous dissociation of bipolar hemiarthroplasty components is an extremely rare complication, rarely reported in the literature. This series highlights its clinical significance, discusses potential risk factors, and underscores the necessity of rigorous postoperative care and follow-up. Not many cases of late bipolar dissociation have been described in the literature worldwide.

Keywords: Bipolar, Dissociation, Hemiarthroplasty, Neck femur.

Indian Journal of Arthroplasty (2024): 10.5005/ijoa-11025-0007

Introduction

Femoral neck fractures in the geriatric age group are increasing in numbers as their life expectancy is on the rise.[1] Bipolar hemiarthroplasty is more popularly used than unipolar prostheses for cases of intracapsular fractures in elderly or neglected cases. While complications such as infection, implant loosening, and dislocation are well-documented and have been extensively studied, this case series involving 4 patients emphasize an uncommon and distinctive complication: The dissociation of the bipolar hemiarthroplasty components.[2–4] This occurrence involves the separation or dislodgment of the inner articulating component from the outer implant, leading to compromised hip function and necessitating revision surgery.

Spontaneous late dissociation of bipolar components is an exceptionally rare complication of bipolar hemiarthroplasty and has hardly been reported in the present literature. The reported cases were mostly earlier designs with leaflets instead of the modern locking ring design and were thought to be due to varus malposition of the femoral head.[5] Georgiou et al. reported 5 cases, 3 of which had early dissociation of the femoral head and outer component following attempted closed reduction after dislocation of the whole bipolar prosthesis like a bottle opener effect. One had damage to the locking mechanism after 2 months of surgery and only 1 case of late spontaneous dissociation (Link prosthesis) after 10 years without any injury.[6] The sudden onset of pain and limp in a well-functioning bipolar replacement should not be ignored and raise suspicion of component dissociation.

We hereby present four cases of late spontaneous component dissociation in patients following bipolar hemiarthroplasty, highlighting the clinical presentation, radiographic findings, and management of this uncommon complication. All the patients presented with pain after 7–14 years of index surgery and were asymptomatic in the intervening period. Through the detailed examination of these cases, we aim to contribute to the understanding of this rare occurrence, provide insights into its potential risk factors, and emphasize the importance of vigilance in postoperative care and follow-up for patients who undergo bipolar hemiarthroplasty. To our knowledge, only a few cases of such late presentation of bipolar component dissociation have previously been reported in the literature (Table 1).

[1–3]Department of Orthopaedics, SN Medical College, Agra, Uttar Pradesh, India

[4]Department of Orthopaedics, Kapoor Orthopedic Center, Agra, Uttar Pradesh, India

[5]Department of Orthopaedics, Lilavati Hospital and Research Centre, Mumbai, Maharashtra, India

[6]Department of Orthopaedics, Pruthi Orthopaedic Care Center, Agra, Uttar Pradesh, India

Corresponding Author: Amrit Goyal, Department of Orthopaedics, SN Medical College, Agra, Uttar Pradesh, India, Phone: +91 8979002051, e-mail: amritgoyal81@gmail.com

How to cite this article: Goyal A, Sharma Y, Gupta M, *et al*. Late Spontaneous Dissociation of Bipolar Hemiarthroplasty Components: A Case Series and Review of Literature. Indian J Arthroplasty 2024;1(1):29–36.

Source of support: Nil

Conflict of interest: Dr Amrit Goyal is associated as the Associate Editor of this journal and this manuscript was subjected to this journal's standard review procedures, with this peer review handled independently of this editorial board member and his research group.

Table 1: Recently published articles on bipolar hemiarthroplasty dissociation

Author name	*Year of publication*	*Number of patients*	*Type of injury and duration from primary surgery*
Vasileios A, Spyridon P	2022	1	Component dissociation following mobilization out of bed (10 years)
Hüseyin Fatih Sevinç	2021	2	Patient 1: Component dissociation following trivial trauma (10 months)
			Patient 2: Component dissociation following reduction of posterior dislocation (NA)
Saini MK et al.	2020	1	Component dissociation following reduction of posterior dislocation (3 weeks)
Bian et al.	2019	4	Component dissociation following reduction of posterior dislocation (2 days–4 weeks)
Lee HH et al.	2008	1	Component dissociation following fall from chair (10 years)
Georgiou et al.	2005	5	Patient 1: Posterior dislocation with simultaneous dissociation while mobilizing out of bed (7 weeks)
			Patient 2: Spontaneous dissociation with no history of trauma (10 years)
			Patient 3: Component dissociation following reduction of posterior dislocation (1 month)
			Patient 4: Component dissociation following reduction of posterior dislocation (3 years)
			Patient 5: Spontaneous dissociation with no history of trauma (2 months)
Hasegawa et al.	2004	6	Spontaneous dissociation due to polyethylene wear (7.5 years: Range between 4.8 and 9.2 years)

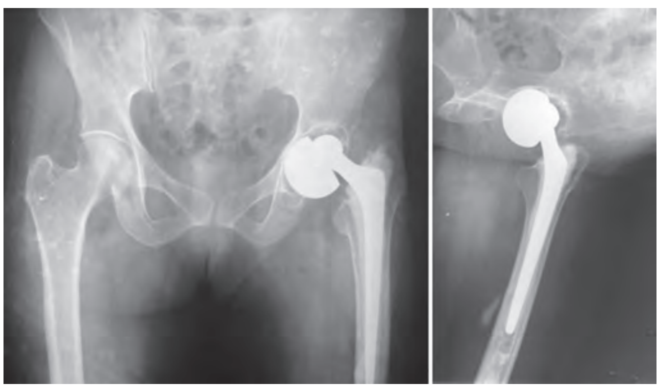


Fig. 1: Preoperative X-ray: The acetabular component separated from the femoral component and lying inferomedially; inner head lying within the native acetabulum

Case Description

Case 1

A 60-year-old female presented to our hospital with complaints of left hip pain and difficulty in walking for the past 3 months, with no history of recent trauma. The intensity of the pain had increased significantly in the past 1 month and she was unable to walk. She had no history of diabetes or hypertension and had undergone a bipolar hemiarthroplasty for a left hip femoral neck fracture 10 years ago by the senior author himself. The patient was asymptomatic for 10 years, was entirely self-sufficient in day-to-day activities, and could ambulate without assistance before developing the pain. There was no neurovascular deficit. On the initial X-rays and CT scan, dissociation of the components of the bipolar hemiarthroplasty, with inferomedial displacement of the acetabular cup component was observed (Figs 1 and 2). There was no evidence of fracture or loosening of the femoral component of the prosthesis.

The patient was planned for conversion of bipolar hemiarthroplasty to total hip arthroplasty (THA). The patient was positioned in the lateral decubitus position and a posterior approach to the left hip was utilized. After opening of the capsule, the head was found to be dissociated, with the polyethylene component also being separated from the liner (Fig. 3). The polyethylene liner was found to be eroded especially in the posterosuperior part, which had most probably caused a late dissociation of the hemiarthroplasty (Inor). A significant amount of debris was present between the polyethylene liner and metal head and also around the implant (Fig. 4). The acetabulum was eroded at multiple places, the maximum defect measuring 2 × 2 cm. Also, the metal head was abutting the acetabulum causing erosion of the superior acetabulum. The patient most probably had an undiagnosed dissociation 1 month back and was walking on the smaller metal head.

The stem bone junction was cleared and was found to be well fixed. A pocket was made in the anterosuperior area above the acetabulum. The stem was placed in this pocket and a retractor was used to push it anteriorly along with the femur for acetabular exposure. The debris was removed, and a thorough curettage of the acetabulum was done. Lytic lesions were present in the acetabulum which were 1–2 cm wide and around 1 cm in depth. These defects were filled with commercially available artificial bone grafts. A cemented acetabular component was placed while retaining the original femoral stem (Fig. 5).

There were no postoperative complications, and the patient was discharged 5 days after the surgery. The patient remained asymptomatic for 2 weeks following which she developed swelling and serous discharge from the incision site. Intravenous antibiotics and anti-allergics were started. The culture report of the discharge aspirate came out to be sterile and the patient's blood counts were normal. The symptoms resolved within a few days and were most probably due to an allergic reaction to the implant/artificial bone graft.

At 1st month follow-up, no complications were observed, and partial weight-bearing was allowed using a walker. At 3rd month follow-up, she was able to walk without any restrictions and was able to return to her day-to-day activities (Figs 6 to 8).

Case 2

An 88-year-old female presented with hip pain for the last month and difficulty in walking for 2 weeks, with no history of recent trauma.

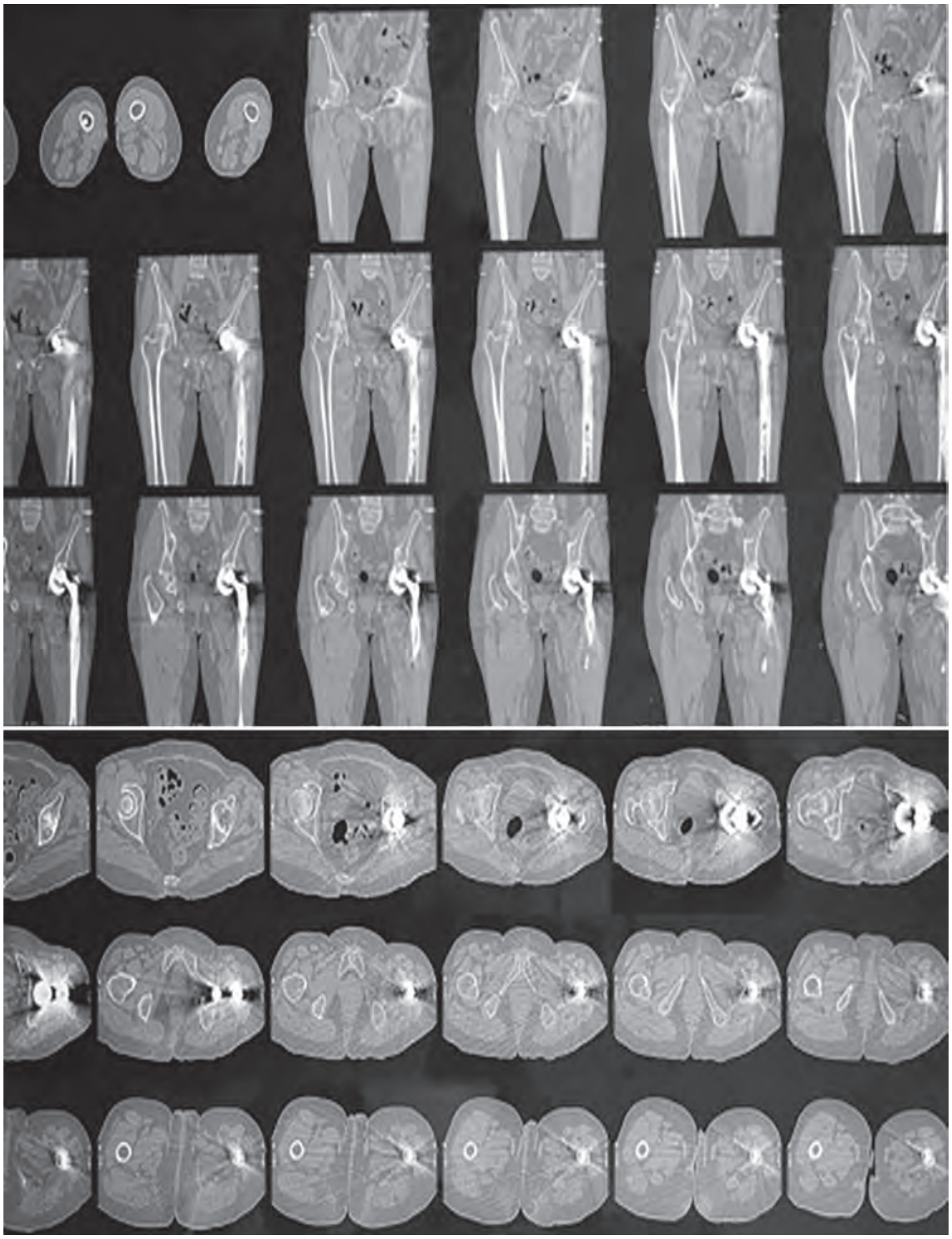


Fig. 2: Preoperative CT scan

The patient had undergone a hemi-replacement arthroplasty for a femoral neck fracture in 2008 and was asymptomatic for the last 14 years. The patient was severely osteoporotic.

On initial X-rays and CT scan (Figs 9 and 10), dissociation of the components of the bipolar hemiarthroplasty was noted. A CT scan was ordered and the patient was planned for a conversion to THA. The patient was placed in the lateral decubitus position and a posterior approach to the left hip was used. On opening the hip joint a lot of dark-stained tissue was present around the metal head and neck junction (Fig. 11). The tissue was removed and was thought to be because of metallosis or polyethylene wear either due to taper corrosion seen on neck or rubbing of the displaced bipolar cup on the metal surface of the neck or metal head. The liner was damaged at the posterosuperior part and had led to the failure of the locking ring and the escape of the metal head. Also, some erosion of the neck was seen may be due to taper corrosion. Since it was superficial and the stem was cemented way down the femur, considering the patient's age and severe osteoporosis decision was made to continue with the same well-fixed stem. Significant chondrolysis was noted on the acetabular cartilage. Erosion of the polyethylene component, as in the previous case, was the most probable cause for component dissociation (XLO implant). However, no bony erosions were found in this case.

The stem was placed in an anterosuperior pocket and retracted anteriorly along with the femur for acetabular exposure and reaming. A cemented acetabular cup was placed while retaining the original stem (Fig. 12).

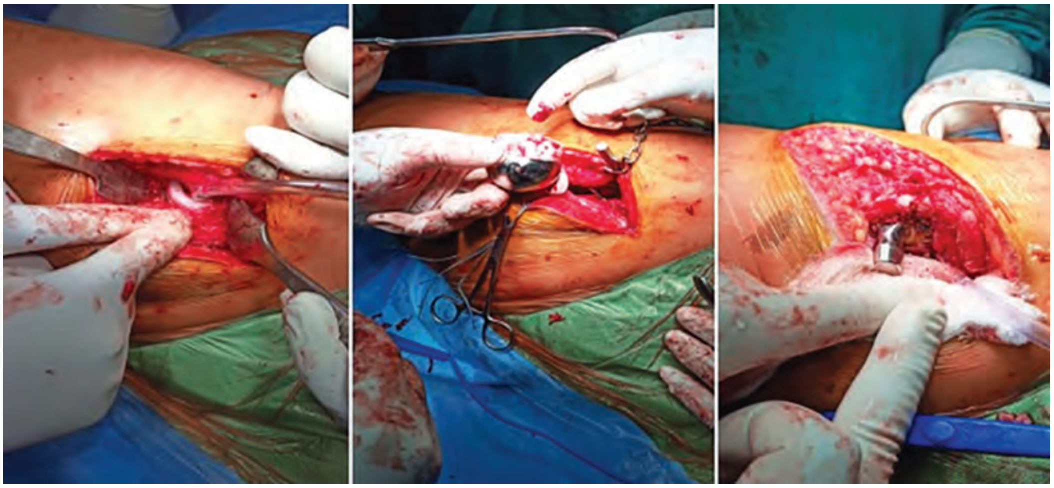


Fig. 3: Intraoperative photographs showing dissociation of bipolar prosthesis components

Fig. 4: Removed prosthesis with worn polyethylene insert and debris

Fig. 5: Immediate postoperative X-ray

Partial weight bearing was started at 1 month, the patient was walking without any support at 3 months and the subsequent follow-ups remained uneventful (Fig. 13).

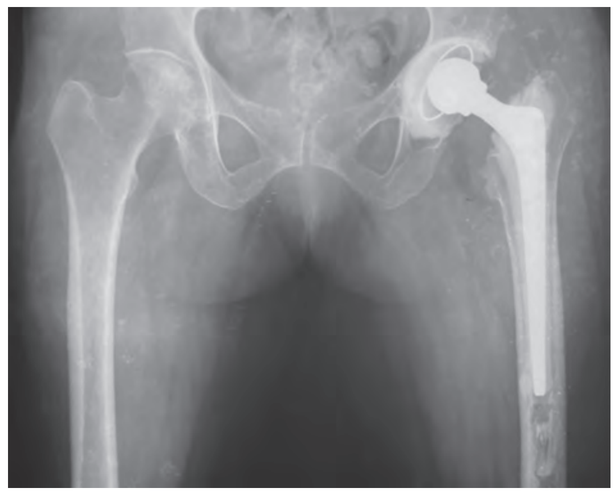


Fig. 6: X-ray at 3rd month follow-up

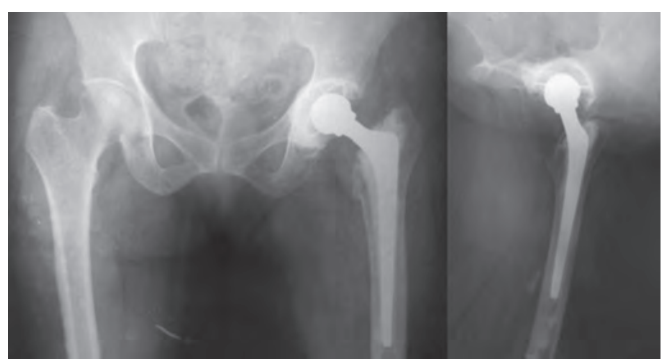


Fig. 7: X-ray at 6th month follow-up

Case 3

A 73-year-old female with a documented history of rheumatoid arthritis presented with pain and an inability to bear weight on her right lower limb following a trivial fall while seated on the toilet. She had previously been ambulatory but experienced a sudden decline in mobility following this incident. Notably, the patient had a complex surgical history, having undergone a right bipolar

Fig. 8: X-ray at 1-year follow-up

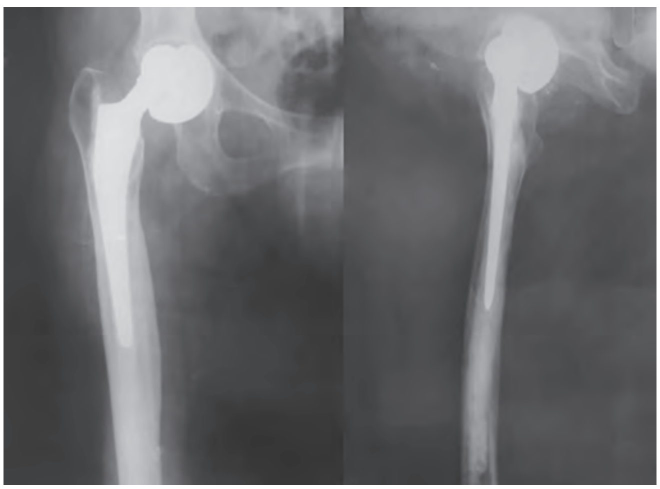


Fig. 9: Preoperative X-ray showing component dissociation with inferomedial displacement of acetabular component

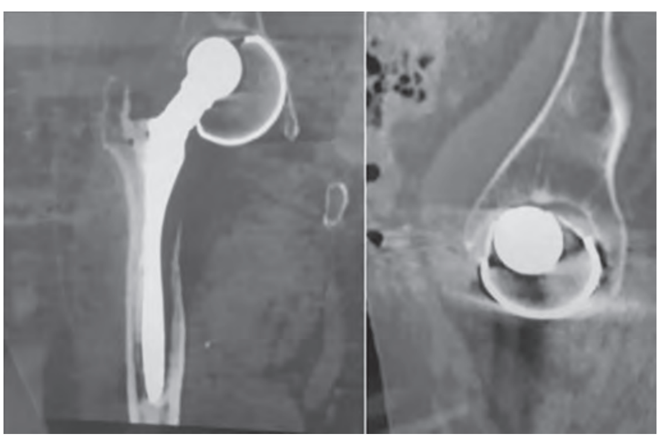


Fig. 10: Preoperative CT scan

hemiarthroplasty 12 years ago for a femoral neck fracture, a total knee replacement on the left side 11 years ago, and a left hip bipolar hemiarthroplasty 10 years ago for another femoral neck fracture.

Radiographic evaluation revealed the dissociation of the bipolar components, with the inner head detached from the outer part (Fig. 14). The patient underwent a revision hemiarthroplasty with a long stem, along with cerclage wires, to address the dissociation and achieve stable fixation as the make of the original implant was not known and matching taper could not be procured (Fig. 15).

The patient's postoperative recovery was uneventful, marked by a gradual improvement in pain and an incremental return of mobility. At the last follow-up appointment, the patient demonstrated significant progress, being ambulatory without assistance and capable of performing daily activities independently.

Case 4

The patient is a 60-year-old female who had undergone a bipolar hemiarthroplasty 7 years ago for a left femoral neck fracture (implant not known), presented with complaints of persistent pain and a noticeable limp on the left side for the last 2 months, prompting further investigation. X-rays were performed, revealing dissociation of the components of the bipolar hemiarthroplasty (Fig. 16). This dissociation likely contributed to the patient's symptoms and compromised the stability of the prosthetic joint.

The decision was made to proceed with a conversion to total hip replacement to address the issues associated with the existing prosthesis. On exposure the acetabular cup and femoral head components were disengaged and the polyethylene liner eroded, compromising the structural integrity of the prosthetic joint. The original femoral stem, however, exhibited secure fixation and was deemed suitable for retention. During surgery, retraction of the retained stem was encountered especially while reaming the acetabulum. A cemented acetabular cup was placed in the proper orientation (Fig. 17).

The postoperative course was uneventful. At the 1-month follow-up, no complications were noted, and the patient was permitted partial weight-bearing with the assistance of a walker. By the 6-month follow-up, she demonstrated significant progress, walking without limitations, and successfully resumed her normal daily activities (Fig. 18).

Discussion

Hip hemiarthroplasty is widely utilized in the management of hip fractures and degenerative hip conditions. The dissociation of hip hemiarthroplasty components is a relatively rare but noteworthy complication that warrants careful consideration and examination. While the overall incidence of dissociation of hip hemiarthroplasty components is low, it is essential to recognize that this complication is not entirely unheard of. Several isolated case reports and limited case series have documented similar occurrences, shedding light on the unique challenges it presents.

The initial documentation of dissociation dates back to 1985 when a case of polyethylene breakage occurred during a Bateman bipolar hemiarthroplasty.[5] This type of failure occurs at the interface between the leaflets and the main body of the bearing insert, specifically where the insert has a pronounced circumferential groove. When the outer cup is aligned in varus, stress is concentrated on this thin circumferential groove, ultimately causing failure.

There are variable mechanisms behind component dissociation. When trying closed reduction of a dislocated bipolar prosthesis, the cup gets locked on to the posterior acetabular rim while applying

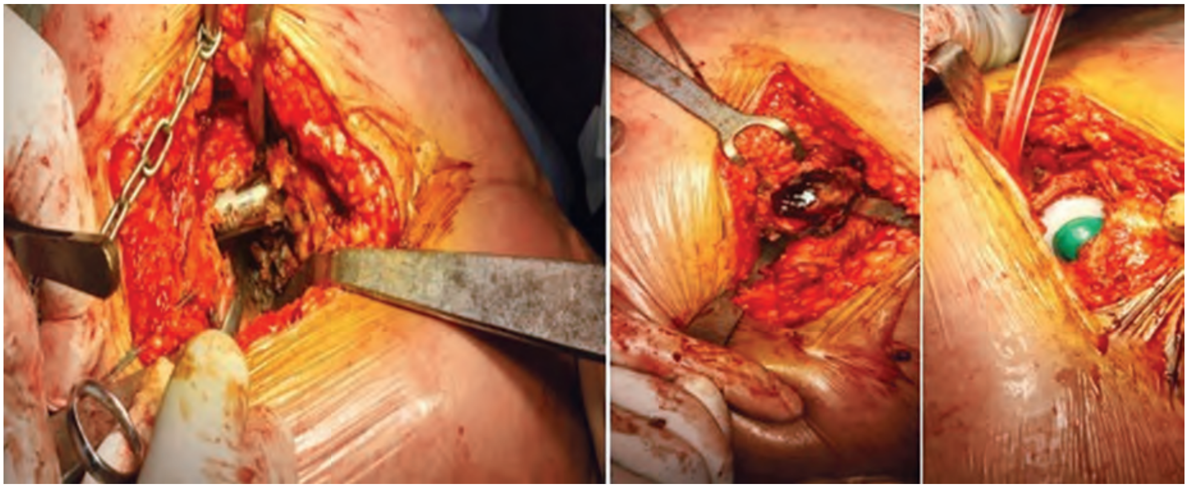


Fig. 11: Intraoperative photographs showing dissociation of bipolar prosthesis components, debris and placement of cemented acetabular component

Fig. 12: Postoperative X-ray

Fig. 13: X-ray at 6th month follow-up

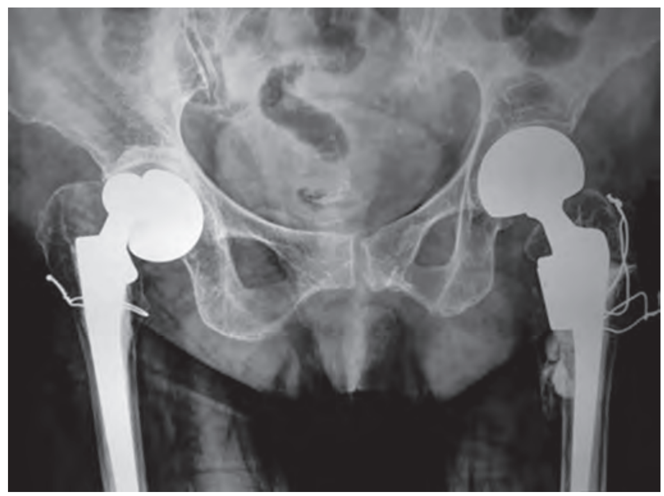


Fig. 14: X-ray at presentation

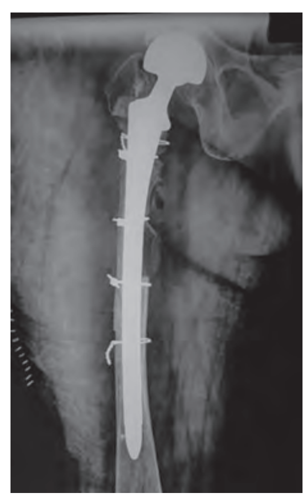


Fig. 15: Postoperative X-ray

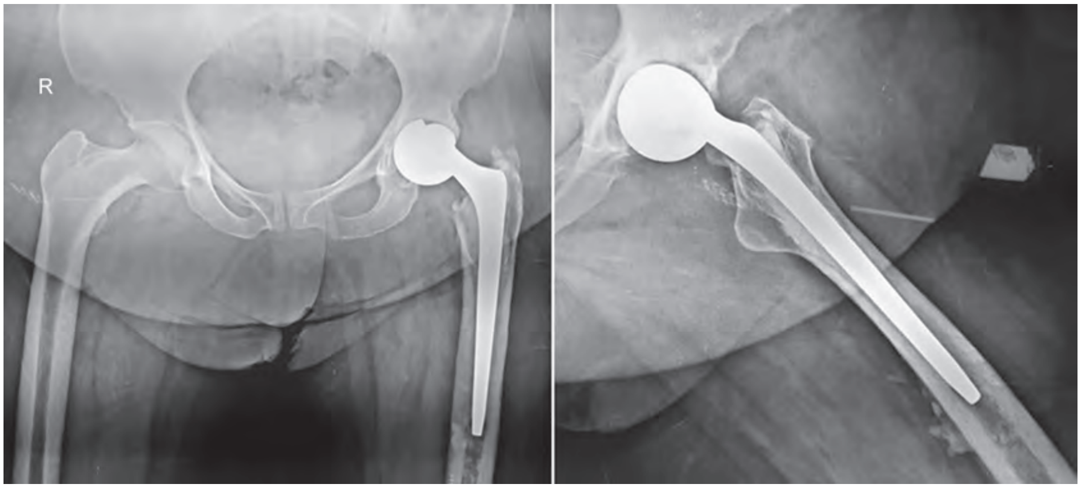


Fig. 16: Preoperative X-ray: The acetabular component separated from the femoral component

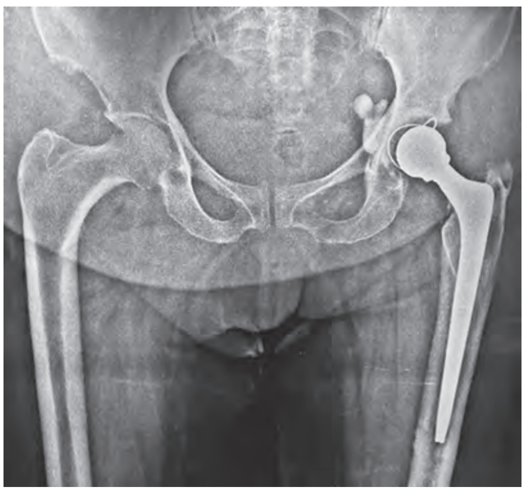


Fig. 17: Postoperative X-ray

Fig. 18: X-ray at 6th month follow-up

limb traction and gets dissociated, often referred to as the 'bottle-opener' effect.[7] Lee et al. documented a dissociation incidence of 13% (7 cases out of 55) during the process of manually reducing a dislocated bipolar hemiarthroplasty.[8] Another potential mechanism involves intra-acetabular dislocation possibly caused by a deficient or faulty polyethylene locking ring.[9] Another plausible mechanism involves the stress loading on the superior lateral segment of the polyethylene due to the varus positioning of the femoral component, potentially leading to dissociation.[10,11] Apart from this, patient factors like high activity levels and design-related issues can also contribute to component dissociation.

In our cases, the cause of late dissociation was attributed to either frictional deformation of the polyethylene or possibly due to a reaction to the polyethylene component, causing failure of the locking mechanism. This led to the inner head becoming dislodged from the outer head, while the outer head retained its position within the acetabulum, in varus alignment (Type II). Debris originating from the rim of the polyethylene insert, causing disintegration of the bipolar mechanism, along with osteolysis and stem loosening has been reported in the past.[12,13] However, no stem loosening was noted in our cases. Only 1 stem was revised due to taper mismatch and unavailability of the original implant.

The occurrence of late dissociation of components in bipolar hemi-replacement is an exceptionally uncommon complication. Although most reports concerning late component dissociation have attributed the problem to the reduction of a dislocated prosthesis, instances of spontaneous late dissociation have been exceedingly rare (Table 1). Vasileios A and Spyridon P reported a case of spontaneous late dissociation in a 68-year-old female 10 years following the index surgery.[14] Only one of the total 5 cases of dissociation reported by Georgiou et al. had a late spontaneous dissociation.[6] In 2014, Hasegawa et al. reported the most extensive case series in the literature on late spontaneous component dissociation following bipolar hemiarthroplasty, comprising seven documented cases, with a mean duration of 7.5 years from the primary surgery.[10] The failure of the self-centering system's locking mechanism was attributed to extensive polyethylene abrasion at the rim, primarily caused by impingement and deformity of the locking ring. They categorized the dissociations into three types based on the position of the locking ring: Type I, where the locking ring is loosened but the femoral ball is not dislocated; type II, where the locking ring is loosened and the inner femoral head is dislocated; and type III, where the inner femoral head is dislocated but locking ring remains attached to the outer cup. Lee HH et al.

reported a case of late dissociation in a 72-year-old woman who had undergone bipolar hemiarthroplasty around 10 years ago after sustaining an injury after falling from a chair.[15] They classified this as a type II failure.

When component dissociation does occur, open reduction remains the treatment of choice. The orthopedic surgeon should weigh the option of potential modifications to prosthetic components or, as demonstrated, conversion to THA. Adopting THA can address future alignment issues, which is particularly advantageous considering the typical age-group of these patients.

Conclusion

In conclusion, we report four cases of late spontaneous dissociation of bipolar hemiarthroplasty components, a rare but increasingly recognized consequence and the first such case report from the Indian subcontinent. Reduction maneuvers for dislocated prostheses should be approached with caution, performed under general anesthesia, and guided by fluoroscopic monitoring. Annual radiographic follow-up should be done for all patients and any early sign of dissociation should be picked up to prevent further complications. Late spontaneous dissociation, while rare, necessitates a nuanced understanding of the contributing factors and a tailored approach to management.

References

1. Kannan A, Kancherla R, McMahon S, et al. Arthroplasty options in femoral-neck fracture: Answers from the national registries. Int Orthop 2012;36(1):1–8. DOI: 10.1007/s00264-011-1354-z.
2. Ekman E, Nurmi H, Reito A, et al. Complications following 250 cemented modular hip hemiarthroplasties. Scand J Surg 2019;108(4): 321–328. DOI: 10.1177/1457496918812226.
3. Calton TF, Fehring TK, Griffin WL, et al. Failure of the polyethylene after bipolar hemiarthroplasty of the hip. A report of five cases. J Bone Joint Surg Am 1998;80(3):420–423. DOI: 10.2106/00004623-199803000-00015.
4. Corteel J, Putz P. Dislocation-dissociation of a bipolar hip prosthesis. Acta Orthop Belg 1996;62(3):173–176. PMID: 8967298.
5. Bateman JE, Berenji AR, Bayne O, et al. Long-term results of bipolar arthroplasty in osteoarthritis of the hip. Clin Orthop Relat Res 1990;251:54–66. PMID: 2295197.
6. Georgiou G, Siapkara A, Dimitrakopoulou A, et al. Dissociation of bipolar hemiarthroplasty of the hip after dislocation. A report of five different cases and review of literature. Injury 2006;37(2):162–168. DOI: 10.1016/j.injury.2005.09.014.
7. Star MJ, Colwell CW Jr, Donaldson WF 3rd, et al. Dissociation of modular hip arthroplasty components after dislocation. A report of three cases at differing dissociation levels. Clin Orthop Relat Res 1992:278:111–115. PMID: 1563139.
8. Lee YK, Park CH, Ha YC, et al. What is the frequency of early dissociation of bipolar cups and what factors are associated with dissociation? Clin Orthop Relat Res 2018;476:1585–1590. DOI: 10.1097/CORR.0000000000000350.
9. Tabutin J, Damotte A. Progressive intra-acetabular dislocation of bipolar hip prostheses: Four cases. Rev Chir Orthop Reparatrice Appar Mot 2004;90(1):79–82. DOI: 10.1016/s0035-1040(04)70011-2
10. Hasegawa M, Sudo A, Uchida A. Disassembly of bipolar cup with self-centering system: A report of seven cases. Clin Orthop Relat Res 2004;425:163–167. DOI: 10.1097/00003086-200408000-00022.
11. Herzenberg JE, Harrelson JM, Campbell DC 2nd, et al. Fractures of the polyethylene bearing insert in Bateman bipolar hip prostheses. Clin Orthop Relat Res 1988;228:88–93. PMID: 3342592.
12. Kobayashi S, Takaoka K, Tsukada A, et al. Polyethylene wear from femoral bipolar neck-cup impingement as a cause of femoral prosthetic loosening. Arch Orthop Trauma Surg 1998;117(6–7): 390–391. DOI: 10.1007/s004020050274.
13. Messieh M, Mattingly DA, Turner RH, et al. Wear debris from bipolar femoral neck-cup impingement: A cause of femoral stem loosening. J Arthroplasty 1994;9(1):89–93. DOI: 10.1016/0883-5403(94)90142-2.
14. Vasileios A, Spyridon P. Dissociation of bipolar hemiarthroplasty of the hip and review of literature. Arthroplasty Today. 2022;16:119–123. DOI: 10.1016/j.artd.2022.05.003.
15. Lee HH, Lo YC, Lin LC, et al. Disassembly and dislocation of a bipolar hip prosthesis. J Formos Med Assoc 2008;107:84–88. DOI: 10.1016/S0929-6646(08)60013-3.

CASE REPORT

Bilateral Knee Arthroplasty in Acromegalic Arthropathy: A Rare Case Report and Literature Review

Plaban N Chowdhury[1], Abhishek Vaish[2], Raju Vaishya[3]

Received on: 20 August 2024; *Accepted on:* 10 September 2024; *Published on:* 01 October 2024

Abstract

Introduction: Acromegalic arthropathy, a rare complication of acromegaly caused by excessive growth hormone (GH) production, primarily affects large joints, leading to pain, stiffness, and functional impairment. Unlike degenerative arthropathy, which is typically due to wear and tear over time, acromegalic arthropathy is driven by the overproduction of GH and insulin-like growth factor 1 (IGF-1), resulting in abnormal cartilage and bone growth. Effective management requires a multidisciplinary approach involving endocrinologists, rheumatologists, and orthopedic surgeons. With a prevalence of 40 to 70 cases per million and diagnosis typically between ages 40 and 50, treatment ranges from conservative early-stage measures to surgical interventions like total knee arthroplasty (TKA) in advanced cases. Despite extensive research, gaps exist in understanding long-term outcomes and treatment efficacy.

Case description: We present a unique and rare case of a 64-year-old female who was diagnosed with acromegalic arthropathy of both knees and managed with bilateral TKA. This case, due to its rarity, provides a valuable opportunity to delve into the complexities of this condition and its management.

Conclusion: Acromegalic arthropathy is a rare joint disorder. Successful outcomes following TKA highlight the effectiveness of surgery in severe cases, emphasizing the need for timely intervention. This underscores the importance of early diagnosis, empowering both patients and healthcare professionals to take proactive steps in managing this condition. The surgical steps and postoperative care are similar to those for other end-stage knee arthritis. A multidisciplinary approach is crucial for effective management.

Keywords: Acromegaly, Arthroplasty, Case report, Knee, Osteoarthritis.

Indian Journal of Arthroplasty (2024): 10.5005/ijoa-11025-0002

Introduction

Acromegalic arthropathy is a rare but debilitating complication of acromegaly, characterized by excessive growth hormone (GH) production and subsequent elevation of insulin-like growth factor 1 (IGF-1). These hormonal imbalances lead to various musculoskeletal abnormalities, including the proliferation of cartilage and bone tissue. GH and IGF-1 stimulate chondrocyte proliferation and extracellular matrix production in the joints, which results in hypertrophic cartilage and abnormal joint growth. This process, over time, leads to joint space narrowing, osteophyte formation, and ultimately, the development of arthropathy.[1] It is a progressive condition that primarily affects the large joints, leading to pain, stiffness, and functional impairment. A key aspect of successfully managing this condition is the multidisciplinary approach involving endocrinologists, rheumatologists, and orthopedic surgeons, which provides a comprehensive and holistic care plan.

Acromegaly leads to the enlargement of bones and soft tissues, which results in joint pain, stiffness, and deformities.[2] Acromegalic arthropathy can significantly impact a person's quality of life and mobility. As the condition progresses, individuals may experience difficulty moving their joints and develop deformities such as enlarged hands and feet.[3] Treatment for acromegalic arthropathy focuses on managing symptoms and preventing further joint damage. It includes conservative treatment in the early stages and surgical intervention in moderate to advanced stages of arthritis.[4]

Acromegaly has a prevalence estimated between 40 and 70 cases per million people, with an annual incidence of about 3–4 cases per million. Diagnosis often occurs between 40 and 50, affecting both genders equally.[5] Existing literature documents the prevalence, pathophysiology, and clinical manifestations of acromegalic arthropathy, but gaps remain regarding long-term outcomes, quality of life impacts, and comparative efficacy of therapeutic interventions.

This case report aims to address these gaps and provide a comprehensive overview of acromegalic arthropathy, including its etiology, clinical manifestations, diagnosis, and management, through the presentation and management of a 64-year-old female with bilateral knee arthritis.

Case Description

A 64-year-old female presented to us with bilateral knee pain for the last 20 years duration. It was insidious in onset, dull aching, and

[1–3]Department of Orthopaedics and Joint Replacement Surgery, Indraprastha Apollo Hospitals, New Delhi, India

Corresponding Author: Plaban N Chowdhury, Department of Orthopaedics and Joint Replacement Surgery, Indraprastha Apollo Hospitals, New Delhi, India, Phone: +91 9957990575, e-mail: plabandoc@gmail.com

How to cite this article: Chowdhury PN, Vaish A, Vaishya R. Bilateral Knee Arthroplasty in Acromegalic Arthropathy: A Rare Case Report and Literature Review. Indian J Arthroplasty 2024;1(1):37–42.

Source of support: Nil

Conflict of interest: None

Patient consent statement: The author(s) have obtained written informed consent from the patient for publication of the case report details and related images.

gradually progressive. It subsided on taking medications and rest. Initially, it was limited to activities like climbing stairs, but now it has started involving her activities of daily living.

She was diagnosed with acromegaly (pituitary macroadenoma) 20 years ago. Her GH and IGF-1 were raised. It was treated with endoscopic transsphenoidal hypophysectomy, but only partial excision of the tumor mass was possible. She later underwent Gamma-knife therapy for ablation of the remaining tumor mass. Since then, she has been on oral Prednisolone 2.5 mg once daily. Despite these interventions, she continued to experience musculoskeletal symptoms, which have progressively worsened over the years.

It is important to note that the onset of her musculoskeletal symptoms occurred concurrently with her diagnosis of acromegaly, suggesting that the severity and progression of her arthropathy may correlate with the partial control of her acromegaly. This timeline emphasizes the connection between the duration and severity of her acromegaly and the development of her joint symptoms.

Her significant medical history, including childhood tuberculosis, glaucoma, and surgical procedures, provides a comprehensive context for her current condition. These conditions and surgeries may have contributed to the progression and severity of her acromegalic arthropathy, and understanding their role is crucial for a holistic approach to her management.

Fig. 1: Frontal face view showing prominent forehead, crease, brow, mandibular enlargement, and nasolabial folds

On general examination, she had coarse facial features, a prominent forehead, a prominent brow, prognathism (mandibular enlargement), a prominent forehead crease, and nasolabial folds. She also had thick eyelids, a large nose, and a large lower lip (Fig. 1). Macroglossia and widely spaced dentition were noted on examination of the oral cavity. She had acral enlargement, i.e., large hands with stubby fingers, large feet, and thick and rough skin (Fig. 2).

On physical examination, there was medial joint line tenderness. The range of motion (ROM) was 5–100° with palpable patella-femoral crepitus. There was no evidence of ligamentous laxity. There was no significant coronal or sagittal plane deformity. Her preoperative Oxford knee score was 18, while his Knee Society Score was 0—the clinical images of both lower limbs along with the knee joint shown (Fig. 3).

A series of X-rays were performed. X-rays of the knees showed an advanced hypertrophic pattern of osteoarthritic changes. Medial joint space reduction, along with multiple loose bodies, was noted. (Fig. 4).

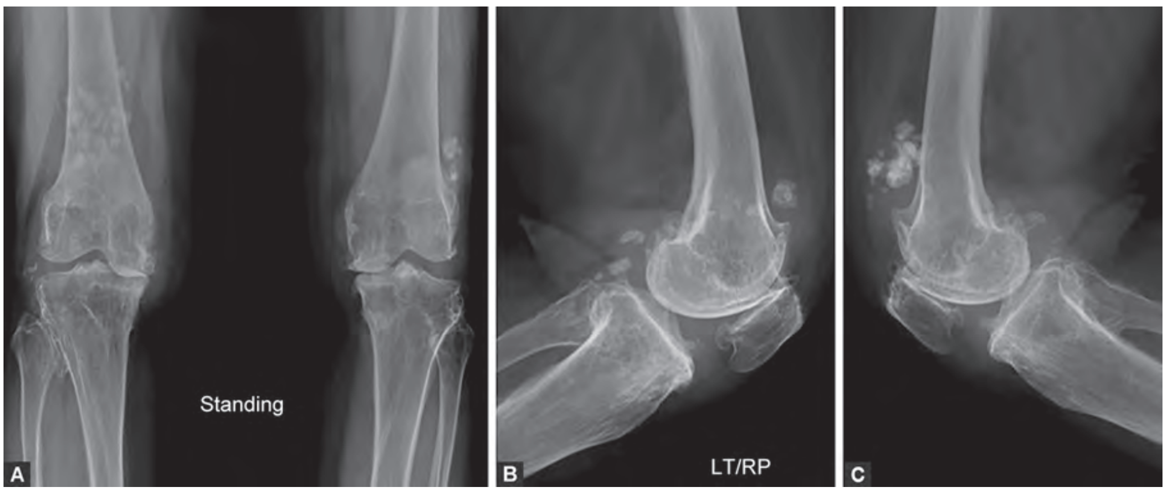
X-ray of the skull revealed calvarial thickening, especially of the inner table, frontal bossing, enlarged paranasal sinuses, and an enlarged sella turcica. The mandible is also characteristically enlarged. The terminal phalangeal tufts become hypertrophied and have a spade-like appearance. Minimal joint space enlargement is noted (Fig. 5). A thorough preoperative assessment of other joints, particularly the spine and hip, was conducted using X-rays, which did not reveal any abnormality.

In addition to analgesics, the patient was also treated with somatostatin analogs following her initial diagnosis of acromegaly, which aimed to control the excessive GH and IGF-1 levels. These medications were intended to manage her underlying condition and potentially alleviate some of the musculoskeletal symptoms. However, despite these interventions, including medical management with somatostatin analogs, her joint pain and stiffness continued to progress, indicating a failure of conservative therapy.

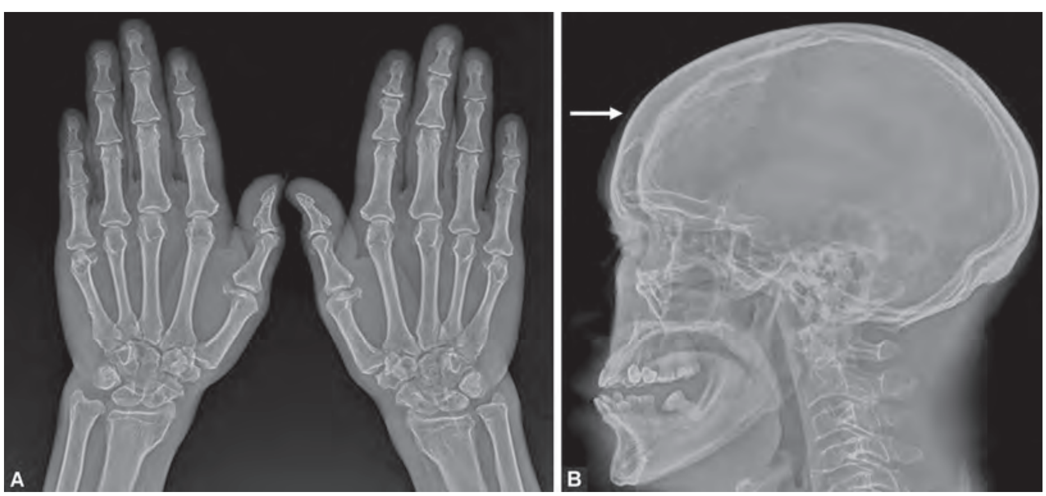
The duration of conservative management, including both analgesics and somatostatin analogs, spanned several years.

Figs 2A and B: Acral enlargement. (A) Large feet and thick, rough skin; (B) Large hands with stubby fingers. The arrow shows the hand of the patient's daughter, which appears significantly smaller than her mother's

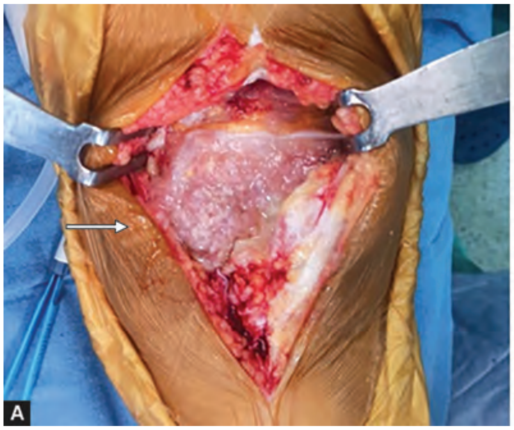
Figs 3A and B: Clinical images of both the knee joints. (A) Frontal view; (B) Side views

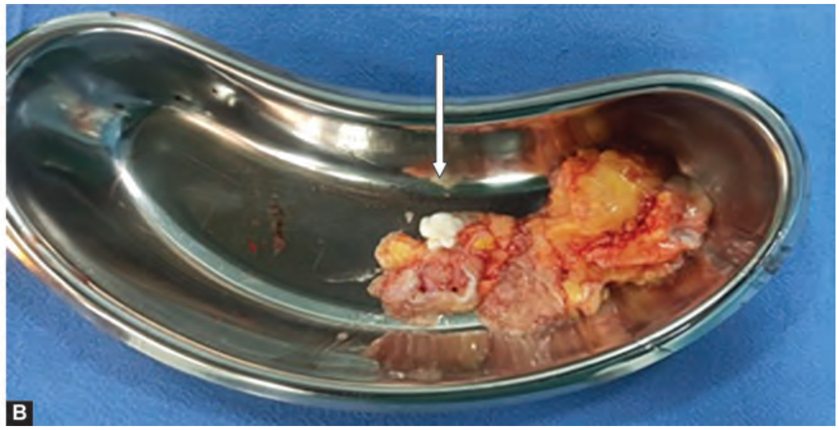


Figs 4A to C: X-rays of both knees showing advanced hypertrophic pattern of osteoarthritic changes, medial joint space reduction, and multiple loose bodies. (A) Antero-posterior view; (B) Lateral view of the left knee; (C) Lateral view of the right knee



Figs 5A and B: (A) X-ray of the hand (antero-posterior view) showing the terminal phalanx, which appears hypertrophied and spade-like; (B) X-ray of the skull (lateral view) shows frontal bossing, enlarged paranasal sinuses, and an enlarged sella turcica. Arrows show frontal calvarial thickening





Figs 6A and B: Intraoperative images of the knee joint showing. (A) Hypertrophied synovium along with loose bodies and calcific hypertrophic bone fragments; (B) Excised synovium along with loose bodies (arrow)

However, as her condition continued to deteriorate, surgical intervention became necessary to manage her severe joint arthropathy.

Perioperative management of steroids in this case was carefully tailored to address the patient's specific needs while mitigating the risks associated with glucocorticoid therapy. The endocrinologist worked closely with the surgical team to ensure optimal management of the patient's steroid regimen. Preoperatively, the patient's steroid dose was adjusted to reflect the increased stress of surgery, with a temporary increase in glucocorticoid dosage to mimic the body's natural response to surgical stress and prevent adrenal insufficiency. During the surgery, a stress dose of intravenous steroids was administered to maintain adequate glucocorticoid levels and support physiological needs. Postoperatively, the steroid dose was gradually tapered back to the patient's usual maintenance level. This approach aimed to balance the need for adequate adrenal support during the perioperative period while minimizing potential complications such as infection or delayed wound healing associated with steroid use. The careful management of steroids ensured the patient's metabolic stability and supported a smooth recovery process.

As such, bilateral sequential TKA was offered and was agreed upon after informed consent. Preoperative workup revealed a bi-fascicular block. Preoperatively, a temporary pacemaker was implanted, and the surgery proceeded. A midline incision was made, followed by a medial parapatellar approach. Upon everting the patella, hypertrophied synovium, loose bodies, and calcific hypertrophic bone fragments were obtained (Fig. 6). The condyles were grossly enlarged. Also, both the menisci appeared thicker and broader.

We evaluated the patient's knee stability intraoperatively. As the patient did not exhibit any degree of ligamentous laxity, it was determined that a standard prosthesis with appropriate soft tissue balancing would be sufficient to achieve joint stability. Therefore, a hinged knee prosthesis was not immediately used. However, a hinged prosthesis was kept as a backup during the procedure to address any unforeseen instability issues that might have arisen during the surgery. A cemented posterior stabilized TKA (Opulent, Meril^{TM}) was performed using conventional techniques (Fig. 7). The patella was also resurfaced. Intraoperative tissue samples were sent for histological analysis.

During the surgery, several notable observations were made. Reaming of the medullary canal revealed a denser and potentially more sclerotic bone structure, which required careful technique to avoid excessive stress. The cortical bone showed increased thickness, potentially impacting the integrity and strength of the reaming process. The fitment of cutting jigs was slightly challenging due to the altered geometry of the femur and tibia, which necessitated careful adjustment to ensure proper alignment and stability. Additionally, there was a notable difficulty in soft tissue balancing, as the increased bone density and altered joint anatomy influenced the alignment and tension of surrounding soft tissues.

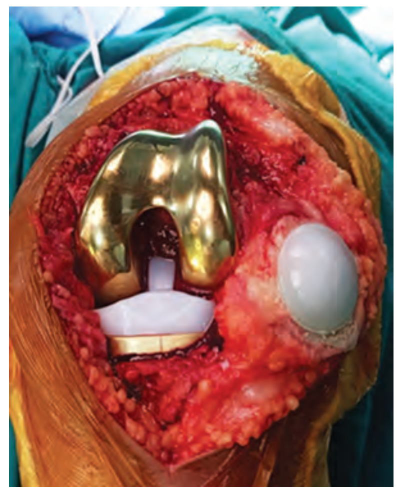


Fig. 7: Intraoperative image of cemented TKA (Opulent, Meril^{TM}) with patellar button *in situ*

With the same technique and implant as the right side, left TKA was performed under general anesthesia. The decision to proceed with simultaneous bilateral TKA was made after thorough deliberation. The patient had been suffering from severe, debilitating pain in both knees for two decades, with the pain progressively worsening to the point of significantly impairing her daily activities. Given the extent of the damage in both knees, addressing only one knee at a time would not have provided adequate relief, potentially prolonging her suffering and limiting her mobility. The decision to perform both TKRs simultaneously was also influenced by the desire to streamline her rehabilitation. A single recovery period would enable a more coordinated and efficient rehabilitation process, allowing for quicker restoration of function and independence, which is crucial in patients with chronic

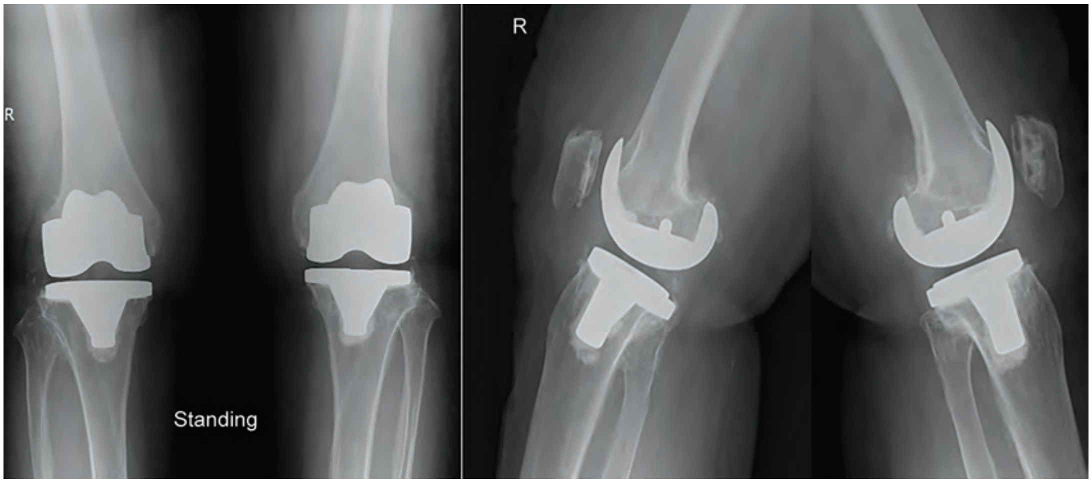


Fig. 8: Postoperative images of the knee joint showing anteroposterior and lateral views of both knees

conditions like acromegaly. The decision was made in consultation with a multidisciplinary team, including the anesthesiologist, endocrinologist, and other relevant specialists. This collaborative approach ensured that all aspects of the patient's health were considered, and the consensus was that a simultaneous bilateral TKR would provide the best outcome for this particular patient.

The operative findings were similar to those of the right knee. Postoperative X-ray showed good alignment of components (Fig. 8).

Perioperative management of steroids in this case was carefully tailored to address the patient's specific needs while mitigating the risks associated with glucocorticoid therapy. The endocrinologist worked closely with the surgical team to ensure optimal management of the patient's steroid regimen. Preoperatively, the patient's steroid dose was adjusted to reflect the increased stress of surgery with a temporary increase in glucocorticoid dosage to mimic the body's natural response to surgical stress and prevent adrenal insufficiency. During the surgery, a stress dose of intravenous steroids was administered to maintain adequate glucocorticoid levels and support physiological needs. Postoperatively, the steroid dose was gradually tapered back to the patient's usual maintenance level. This approach aimed to balance the need for adequate adrenal support during the perioperative period while minimizing potential complications such as infection or delayed wound healing associated with steroid use. The careful management of steroids ensured the patient's metabolic stability and supported a smooth recovery process.

The patient received compression stockings, mechanical calf pumps, and Inj low molecular weight heparin once daily as postoperative thromboprophylaxis. She underwent the same postoperative physiotherapy protocol as other TKA patients in the institution. Static quadriceps exercises and knee bending 0–90° were started on postoperative day (POD) 1, and then 0° to maximal flexion as tolerated from POD 2 onwards. Full-weight bearing was allowed immediately post-operation.

At 12 months of follow-up, she had a ROM of 0–110° bilaterally, with good function and no pain. However, she has been advised to have regular follow-ups to check the progress of her arthroplasty.

Discussion

Acromegaly arises from an overproduction of GH, primarily due to a pituitary adenoma. This tumor stimulates the production of GH, which, in turn, stimulates the liver to produce IGF-1. IGF-1 is responsible for the growth-promoting effects of GH, including the development of acromegalic arthropathy.[6] Acromegalic arthropathy primarily affects the large joints, such as the hips, knees, and shoulders.[3] Over time, the affected joints may become deformed, resulting in loss of function and mobility.

In patients with acromegaly, bone strength and bone mineral density (BMD) are often affected due to chronic exposure to elevated levels of GH. Although acromegaly is typically associated with increased bone density in some areas, the overall impact on bone strength can be complex. Elevated GH levels stimulate excessive bone formation, leading to increased trabecular bone density, but this is not always accompanied by improved bone quality. The excessive bone turnover and abnormal bone remodeling seen in acromegaly can result in a compromised bone matrix and increased risk of fractures despite higher BMD measurements. Thus, while patients with acromegaly may present with seemingly higher BMD, bone strength and structural integrity can still be significantly impaired, necessitating careful monitoring and management to address potential bone-related complications.[7]

The diagnosis of acromegalic arthropathy is based on clinical features, imaging studies, and laboratory tests. X-rays, magnetic resonance imaging (MRI), and computed tomography (CT) scans can help visualize joint changes and assess the severity of the disease.[8] The GH and IGF-1 levels can help confirm the diagnosis of acromegaly and monitor disease progression.

Managing acromegalic arthropathy involves a multidisciplinary approach, including endocrinologists, rheumatologists, and orthopedic surgeons. Medical treatment includes using somatostatin analogs, dopamine agonists, and GH receptor antagonists, which can help control GH and IGF-1 levels, thereby reducing joint symptoms.[9] Intra-articular corticosteroids or hyaluronic acid injections may temporarily relieve joint pain and inflammation. Physical therapy can help improve joint mobility, strengthen muscles, and reduce pain. In severe cases, joint replacement surgery may be necessary to restore function.[10]

Akkaya et al.,[11] in their study on acromegalic arthropathy on 15 patients (22 hips) with a mean follow-up of 12 years (range 4–20), concluded that total hip arthroplasty (THA) could result in successful clinical and functional outcomes in patients with acromegalic arthropathy of the hip. It is worth mentioning that after an extensive search of the electronic database, there was no published literature on TKA on acromegalic arthropathy of the knee. Hence, this study is the first of its kind.

Conclusion

Acromegalic arthropathy is a rare disorder that directly affects bones and joints. The successful clinical and functional outcomes observed following TKA in this patient underscore the potential effectiveness of surgical intervention in managing severe acromegalic arthropathy. These findings have important implications for clinical practice, emphasizing the need for heightened awareness and timely intervention in patients with acromegaly to prevent severe joint degeneration and improve overall outcomes. The operative steps are the same as those for end-stage knee arthritis due to any cause. The postoperative antibiotic protocol, thromboprophylaxis, and rehabilitation protocol remain the same. Early diagnosis and a multidisciplinary approach involving endocrinologists, rheumatologists, and orthopedic surgeons are crucial for successfully managing this condition.

Declaration

CRediT Statement

- PNC: Concept, Literature search, Manuscript writing, editing, and final approval.
- AV: Concept, Literature search, Manuscript writing, editing, and final approval.
- RV: Concept, Literature search, Manuscript writing, editing, and final approval.

References

1. Al Dallal S. Acromegaly: A challenging condition to diagnose. Int J Gen Med 2018;11:337–343. DOI: 10.2147/IJGM.S169611.
2. Chanson P, Salenave S. Acromegaly. Orphanet J Rare Dis 2008;3:17. DOI: 10.1186/1750-1172-3-17.
3. Lavrentaki A, Paluzzi A, Wass JA, et al. Epidemiology of acromegaly: Review of population studies. Pituitary 2017;20(1):4–9. DOI: 10.1007/s11102-016-0754-x.
4. Cirolia JT. Acromegalic arthropathy. J Orthop Sports Phys Ther 2019;49(11):864. DOI: 10.2519/jospt.2019.8302.
5. Melmed S. Medical progress: Acromegaly. N Engl J Med 2006;355(24):2558–2573. DOI: 10.1056/NEJMra062453.
6. Laron Z. Insulin-like growth factor 1 (IGF-1): A growth hormone. Mol Pathol 2001;54(5):311–316. DOI: 10.1136/mp.54.5.311.
7. Gottfried HM, McCormick DL. Bone metabolism and growth hormone in acromegaly: A review. J Endocrinol Metab 2004;89(9): 4081–4090.
8. Claessen KMJA, Canete AN, de Bruin PW, et al. Acromegalic arthropathy in various stages of the disease: An MRI study. Eur J Endocrinol 2017;176(6):779–790. DOI: 10.1530/EJE-16-1073.
9. Giustina A, Barkan A, Beckers A, et al. A consensus on the diagnosis and treatment of acromegaly comorbidities: An update. J Clin Endocrinol Metab 2020;105(4):dgz096. DOI: 10.1210/clinem/dgz096.
10. Gadelha MR, Kasuki L, Lim DST, et al. Systemic complications of acromegaly and the impact of the current treatment landscape: An update. Endocr Rev 2019;40(1):268–332. DOI: 10.1210/er.2018-00115.
11. Akkaya M, Pignataro A, Sandiford N, et al. Clinical and functional outcome of total hip arthroplasty in patients with acromegaly: Mean 12 year follow-up. Int Orthop 2022;46(8):1741–1747. DOI: 10.1007/s00264-022-05447-5.

CASE REPORT

Bilateral Fused Hips with Stiff Spine in Ankylosing Spondylitis with Subtrochanteric Fracture Right Hip

Anil Thomas Oommen[1], Augustine Jaison Paul[2], Christo Jeyaraj[3], Ramu Viswarajan V[4]

Received on: 10 July 2024; *Accepted on:* 04 September 2024; *Published on:* 01 October 2024

Abstract

Background: Ankylosing spondylitis (AS) presents with hip and spine stiffness at total hip arthroplasty (THA) with mobility restriction. Reduced spinopelvic mobility is associated with spine stiffness, especially bilateral fused hips.

Case report: We present a rare case of bilateral fused hips due to AS with a traumatic subtrochanteric fracture of the right femur—preoperative planning with anesthetic considerations included risk assessment for bilateral vs unilateral and mobilization after the procedure. Simultaneous bilateral cementless THA using a modified Hardinge approach with modular femoral component (SROM, Depuy USA) to achieve fracture stabilization was done, followed by gradual mobilization. Care was taken to ensure correct femoral and acetabular component positioning, considering spine stiffness and loss of spinopelvic mobility. The patient is doing well at 3 years with a stiff spine in extension, walking independently, the ability to sit comfortably, and a good functional outcome.

Conclusion: Simultaneous bilateral THA had to be considered in this unusual case of AS, although not ideal, with risk consent for achieving mobility following significant stiffness and disability.

Keywords: Ankylosing spondylitis, Case report, Stiff hips, Subtrochanteric fracture.

Indian Journal of Arthroplasty (2024): 10.5005/ijoa-11025-0003

Introduction

Ankylosing spondylitis (AS) presents with varying degrees of hip and spine stiffness. The loss of spinal flexibility affects spinopelvic mobility with the coexistence of spine and hip stiffness. Significant spine stiffness is seen at presentation for total hip arthroplasty (THA) in these individuals with bilaterally stiff hips. The risk for fractures in AS has been described.[1] However, subtrochanteric fracture with bilateral fused hips in AS has not been reported. Spinopelvic mobility at THA and acetabular component position is essential to achieve optimal outcomes.[2,3] Cementless THA in AS provides a good outcome. Total hip arthroplasty restores movement at the hip with significant functional improvement, although the spine stiffness remains unchanged in AS.

Case Description

A 45-year-old gentleman with bilateral fused hips and stiff spine with AS presented with a right hip subtrochanteric fracture after a fall at home (Fig. 1). He had decreased mobility in both hips and spine (Figs 2A to D) before the fall and was walking with a stiff gait pattern. He had complaints of back pain as well as bilateral hip pain with progressive stiffness over the past 20 years. He has been on regular treatment with disease-modifying drugs for the past 4 years and could walk with stiff hips and spine for about 1 km without pain or discomfort. He was restricted to the bed after a fall 2 weeks before the presentation at our center. His findings revealed significant restriction of movements in the left hip with a flexion deformity of 40° and an external rotation deformity of 30° with a jog of further movement. He was found to have a stiff lumbar and cervical spine both on clinical and radiological examination. His spinopelvic mobility could not be assessed due to his inability to sit or stand after the fracture of the right femur.

A detailed clinical examination was done before preoperative planning. The stiff cervical spine with a difficult airway, possible anesthetic challenges, and risks vs benefits of staged vs bilateral were considered and discussed with the patient before a decision was made for this challenging situation. The option for internal fixation of the fracture was discussed so that planning for THA could be done after fracture healing. Perioperative care and the need for THA as soon as possible were a source of concern for the patient. He was, however, waiting for a THA and, after discussion with the family, was very keen to undergo bilateral hip replacement after understanding the possible risks. Blood investigations included total protein of 7.3 gm/dL, platelet counts of 304,000/mm^3, and total counts of 10,600/mm^3. Simultaneous bilateral THA was carefully planned to facilitate post-op

[1–4]Department of Orthopaedics, Christian Medical College Hospital, Vellore, Tamil Nadu, India

Corresponding Author: Anil Thomas Oommen, Department of Orthopaedics, Christian Medical College Hospital, Vellore, Tamil Nadu, India, Phone: +04162282081, e-mail: lillyanil@cmcvellore.ac.in; anilthomaslilly@yahoo.com

How to cite this article: Oommen AT, Paul AJ, Jeyaraj C, *et al*. Bilateral Fused Hips with Stiff Spine in Ankylosing Spondylitis with Subtrochanteric Fracture Right Hip. Indian J Arthroplasty 2024;1(1): 43–46.

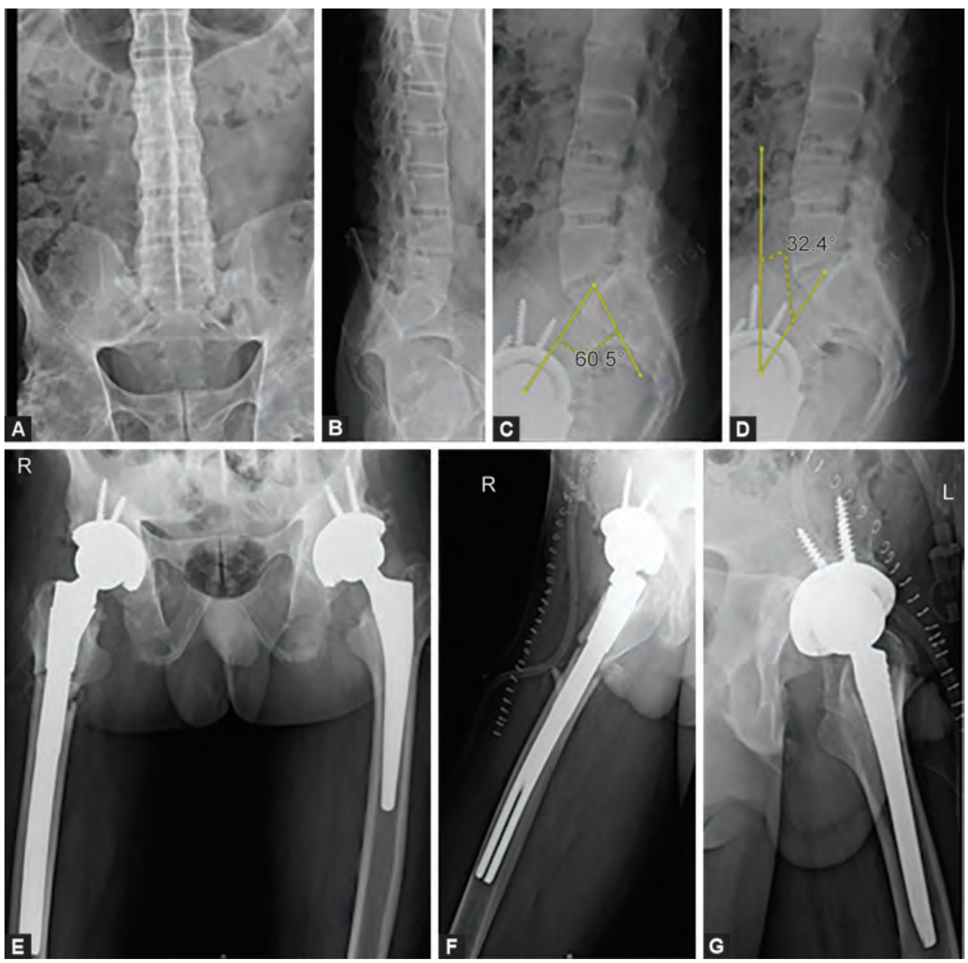
Source of support: Nil

Conflict of interest: Dr Anil Thomas Oommen is associated as the Editorial Board member of this journal and this manuscript was subjected to this journal's standard review procedures, with this peer review handled independently of this editorial board member and his research group.

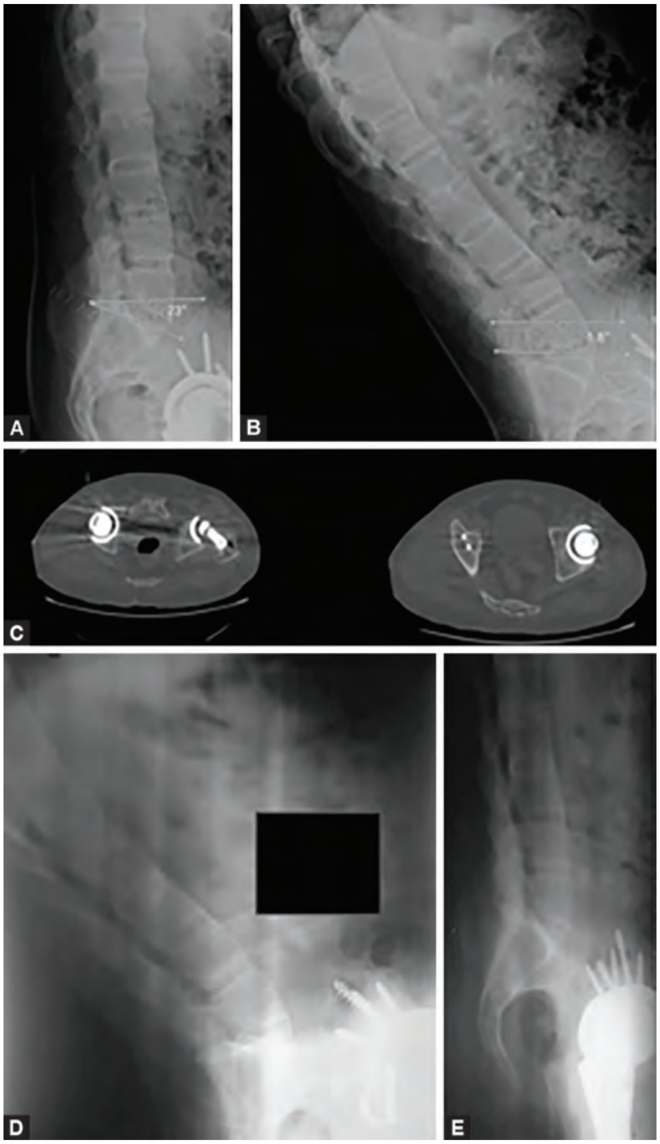
Patient consent statement: The author(s) have obtained written informed consent from the patient for publication of the case report details and related images.

rehabilitation and ambulation and avoid the risks of subsequent difficult anesthesia.[4] A modified lateral approach was used for both hips.[5] This approach is routine in our unit for all THAs, which do not require posterior reconstruction. Bilateral hip arthritis requiring THA is usually carried out in the same sitting in our unit after a detailed anesthetic evaluation. The preoperative planning included templating and planning for a modular SROM (DePuy, USA) femur component on the right side and a cementless Corail (DePuy, USA) for the left side. Pinnacle (DePuy, USA) acetabulum was planned for both hips. The right hip procedure was done first with an extension of the modified lateral approach to expose the fracture and stabilize the fragments during femur preparation. The preparation and fixation were similar to subtrochanteric shortening for complex THA described.[6] Femur preparation was done judiciously to achieve optimal sizing and stabilization of the fracture with the modular femoral component. Stable fixation was achieved with a 15 × 20 × 225 SROM and a 20-B metaphyseal sleeve for the femoral component. Bone grafting was done using bone obtained from the head. The left hip was done in the same sitting with screws used for additional fixation of the cementless acetabular components (Pinnacle, DePuy USA) for both hips (Figs 2E to G). Care was taken regarding component positioning to achieve normal acetabular component anteversion. Left hip arthroplasty was carried out after the right hip as the patient was stable throughout the procedure, with an uneventful immediate postoperative period. He was made to sit on the first postoperative

Fig. 1: A 45-year-AS male with bilateral stiff hips and subtrochanteric fracture right femur with a stiff spine. The pelvic tilt is posterior with the obturator foramen view suggestive of obliteration of lumbar lordosis, which is seen in the follow-up X-rays as well



Figs 2A to G: (A and B) Lumbosacral (LS) spine AP (anteroposterior) and lateral with typical changes of AS and loss of lumbar lordosis; (C and D) Post-op standing X-rays lateral LS spine showing a pelvic incidence of 60.5° and a pelvic tilt of 32.4°; (E to G) Post-op X-ray with long SROM Pinnacle (DePuy, USA) right hip with bone graft and Corail pinnacle left hip anteroposterior and lateral views



Figs 3A to E: (A and B) Post-op standing sacral slope (SS) of 23° compared to sitting SS of 1.8°. The spine extension is obvious at sitting; (C) CT evaluation of anteversion in both hips measured 12.5° at the right hip and 12.6° at the left hip; (D and E) Xray LS spine lateral sitting and standing at follow-up showing spine stiffness in extension

day. He was ambulated with protected weight-bearing on the right and could sit comfortably by the end of 1 week. He was ambulating comfortably with a walker, continuing protected weight-bearing for 2 months, gradually progressing to full weight-bearing. He was weaned off the walker gradually after 6 months.

The acetabular inclination was 44.7° on the right and 49.6° on the left hip. The spine evaluation was done with radiographs in the sitting and standing positions when he could sit comfortably, and the pelvic tilt was calculated (Figs 2C and D). The sacral tilt showed a 21.2° change, while the lumbar lordosis angle changed by only 3.1° between sitting and standing (Figs 3A and B). The spine stiffness was evident in the sitting position with the extension required to achieve a comfortable sitting position (Fig. 3). The anteversion in both hips was calculated with a CT evaluation. Anteversion of the right acetabular component was 12.6°, and the left acetabulum was 12.5° (Fig. 3C). His Harris hip score (HHS) increased from 14 to 83; SF 12 was 54 and 62 for the physical and mental components, respectively, with the WOMAC score of 16 indicating an overall significant improvement in functional outcome.[7]

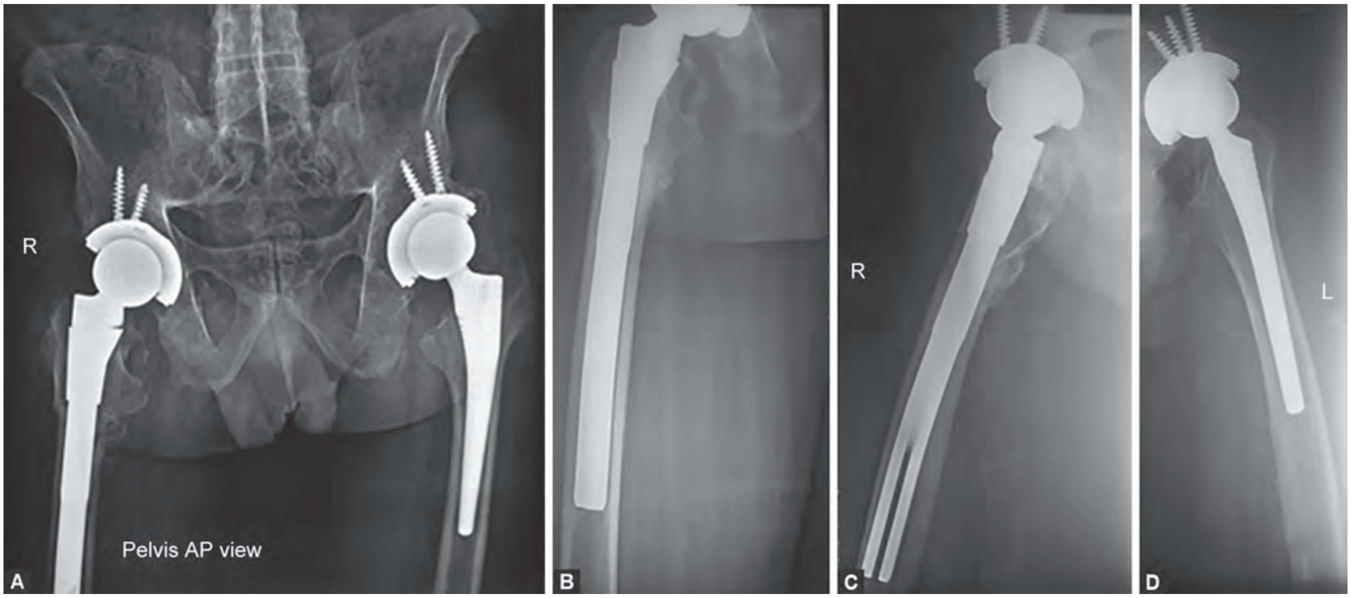
The fracture progressed to complete union with clinical and radiological follow-up (Figs 4A to D). He is ambulating independently at 3 years with the ability to sit comfortably with spine extension because of the spine stiffness (Figs 3D and E).

Discussion

Bilateral fused hips in AS are disabling and require THA to restore joint mobility. The aim would be to restore the center of rotation and achieve stable fixation with cementless implants in hips with good bone stock. The spine is stiff with the stuck sitting spinopelvic mobility pattern.[3,7,8] This spinopelvic mobility pattern seen with the fused spine in AS requires an extension of the spine to enable a comfortable sitting position with the thighs parallel to the floor. The pelvic incidence and change in sacral tilt were identical at post-op and review with spine stiffness. The pre-op assessment is essential, especially with associated spine stiffness.[2,7,9] Our patient had fused hips for bilateral THA, with a subtrochanteric fracture presenting two weeks after the injury. He was keen to undergo bilateral THA to restore mobility and consented to the same after risk considerations. Bilateral THA was performed after careful planning, although staged THA could have been considered for reduced risk of perioperative complications. The spinopelvic mobility is restricted, and anteversion of the acetabulum needs to be reduced in these fused hips to avoid posterior impingement and anterior dislocation.[3,10] Total hip arthroplasty in AS has associated risks, including late dislocation, which must be considered when planning for the same.[11]

A proximal femur fracture with a fused hip poses a challenging situation for THA.[12] The subtrochanteric fracture stabilization and hip arthroplasty were performed using the SROM (DePuy USA) femoral component. Femur fracture with bilateral fused hips in AS has not been reported. The risk of fracture in AS exists in the hip and the vertebrae.[1]

Bilaterally fused hips with bony ankylosis have a severe restriction of daily activity. The mobility is significantly reduced, and the spinopelvic mobility is also affected. The spine was fused, as evidenced by the preop and post-op spine X-rays. The loss of spinopelvic mobility is like a stuck sitting pattern. Movements are restricted to walking with a stiff spine and hips and lying supine. Osteosynthesis for the fracture was considered; however, the individual who was preparing for hip arthroplasty was not keen and wanted to go ahead with arthroplasty, being aware of the possible risks. Fracture stabilization and mobility of the hip joints were achieved at THA with a long modular stem. Fracture stability was achieved, enabling gradual mobilization. The mobility, as well as weight-bearing, was gradually increased based on the clinical and radiological union. The acetabular component positioning was done with care to avoid increased anteversion, compensate for the change in spinopelvic mobility, avoid impingement, and provide a stable functional hip joint. Our patient is comfortable with the ability to walk, sit, and stand comfortably, having residual spine stiffness with spine extension to enable sitting with the thighs



Figs 4A to D: (A) X-ray at 4 months post-op showing good progress in the union at the right subtrochanteric fracture; (B and C) AP and lateral views of the right hip and femur at 1 year with evidence of fracture union; (D) left hip with implants well integrated

parallel to the floor. This pattern of spine stiffness is seen especially in AS, with movement occurring predominantly only at the hips after THA in these stiff individuals.

Conclusion

Bilateral fused hips with subtrochanteric fracture and spine stiffness have not been reported so far. Fracture stability with the restoration of joint mobility is justified in this unusual case of AS with stiff hips and spine and associated subtrochanteric fracture. Fixation and THA with the restoration of joint mobility were achieved with an extended modular femoral component. Bilateral THA rather than staged THA, although not ideal, was carried out in this unusual case to facilitate early mobilization after carefully considering risks, spinopelvic mobility, and perioperative care. The overall functional outcome has significantly improved, and he is doing well at 3-year follow-up.

References

1. Zhang M, Li XM, Wang GS, et al. The association between ankylosing spondylitis and the risk of any, hip, or vertebral fracture: A meta-analysis. Medicine (Baltimore) 2017;96(50):e8458. DOI: 10.1097/MD.0000000000008458.
2. Stefl M, Lundergan W, Heckmann N, et al. Spinopelvic mobility and acetabular component position for total hip arthroplasty. Bone Joint J 2017;99-B(1 Supple A):37–45. DOI: 10.1302/0301-620X.99B1.BJJ-2016-0415.R1.
3. Lum ZC, Coury JG, Cohen JL, et al. The current knowledge on spinopelvic mobility. J Arthroplasty 2018;33(1):291–296. DOI: 10.1016/j.arth.2017.08.013.
4. Lin D, Charalambous A, Hanna SA. Bilateral total hip arthroplasty in ankylosing spondylitis: A systematic review. EFORT Open Rev 2019;4(7):476–481. DOI: 10.1302/2058-5241.4.180047.
5. Mulliken BD, Rorabeck CH, Bourne RB, et al. A modified direct lateral approach in total hip arthroplasty: A comprehensive review. J Arthroplasty 1998;13(7):737–747. DOI: 10.1016/s0883-5403(98)90024-9.
6. Oommen AT, Chandy VJ, Jeyaraj C, et al. Subtrochanteric femoral shortening for hip centre restoration in complex total hip arthroplasty with functional outcome. Bone Jt Open 2020;1(5):152–159. DOI: 10.1302/2633-1462.15.BJO-2020-0023.R1.
7. Innmann MM, Merle C, Gotterbarm T, et al. Can spinopelvic mobility be predicted in patients awaiting total hip arthroplasty? A prospective, diagnostic study of patients with end-stage hip osteoarthritis. Bone Joint J 2019;101-B(8):902–909. DOI: 10.1302/0301-620X.101B8.BJJ-2019-0106.R1.
8. Innmann MM, Merle C, Phan P, et al. How can patients with mobile hips and stiff lumbar spines be identified prior to total hip arthroplasty? A prospective, diagnostic cohort study. J Arthroplasty 2020;35(6S):S255–S261. DOI: 10.1016/j.arth.2020.02.029.
9. Luthringer TA, Vigdorchik JM. A preoperative workup of a “hip-spine” total hip arthroplasty patient: A simplified approach to a complex problem. J Arthroplasty 2019;34(7S):S57–S70. DOI: 10.1016/j.arth.2019.01.012.
10. Heckmann N, McKnight B, Stefl M, et al. Late dislocation following total hip arthroplasty: Spinopelvic imbalance as a causative factor. J Bone Joint Surg Am 2018;100(21):1845–1853. DOI: 10.2106/JBJS.18.00078.
11. Blizzard DJ, Penrose CT, Sheets CZ, et al. Ankylosing spondylitis increases perioperative and postoperative complications after total hip arthroplasty. J Arthroplasty 2017;32(8):2474–2479. DOI: 10.1016/j.arth.2017.03.041.
12. Malhotra R, Khurana A, Shekhar S, et al. Proximal femoral fracture in ankylosed hip treated with primary total hip arthroplasty: Technical tips with report of two cases. J Clin Orthop Trauma 2020;11(1):99–104. DOI: 10.1016/j.jcot.2019.06.014.