Original Article

A Prospective Study on Acetabular Cup Positioning Using Anatomical Landmarks in Primary Total Hip Arthroplasty at a Tertiary Care Center in Mumbai

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Abstract

Background: Accurate acetabular cup positioning in total hip arthroplasty (THA) reduces complications such as dislocation and wear. While the Lewinnek safe zone guides placement, freehand methods vary. Anatomical landmarks like the transverse acetabular ligament offer a cost-effective alternative. This study evaluated their accuracy and early outcomes at a Mumbai tertiary center. **Material and Methods:** This prospective observational study included 50 patients (52 hips) undergoing primary uncemented total hip arthroplasty at a tertiary care hospital in Mumbai over one year. All surgeries were performed by a single experienced surgeon using a posterolateral approach, with acetabular cup placement guided by anatomical landmarks. Intraoperative stability and range of motion were assessed. Postoperative evaluation used standardized anteroposterior pelvic radiographs, with CT scans when required, to measure inclination and anteversion using the modified Murray method. Ethical approval and informed consent were obtained. Data were analyzed descriptively, with outliers defined beyond the Lewinnek safe zone, and functional outcomes assessed using Harris Hip Score at follow-up. **Results:** The mean radiographic inclination was 41.2° ± 4.8° (range 32°–52°), and mean anteversion was 16.8° ± 5.2° (range 6°–28°). Overall, 88% of cups (46/52) fell within the Lewinnek safe zone for both parameters, with 94% within safe inclination and 90% within safe anteversion. Only four hips (7.7%) were outliers, primarily in patients with severe preoperative dysplasia or obesity (BMI >30). No intraoperative complications related to cup placement occurred, and mean surgical time was 78 ± 12 minutes. At 3-month follow-up, the mean HHS improved significantly from 42.6 ± 8.4 preoperatively to 88.4 ± 6.2 ($p<0.001$), with no dislocations reported. Two patients had transient sciatic nerve palsy that resolved conservatively. **Conclusion:** Anatomical landmark-guided positioning of the acetabular cup in primary THA achieved high accuracy within the safe zone in the majority of cases, comparable to more resource-intensive navigation techniques. This simple, reproducible method offers a reliable alternative in settings with limited access to advanced technology, promoting consistent outcomes and low early complication rates. Further long-term studies are warranted to confirm durability.

Keywords: Acetabular cup positioning, anatomical landmarks, transverse acetabular ligament, total hip arthroplasty, Lewinnek safe zone, prospective study.

Received: 02 April 2026 **Revised: 20 April 2026** **Accepted: 04 May 2026** **Published: 13 May 2026**

Introduction

Total hip arthroplasty (THA) is a highly successful procedure for end-stage hip disorders, providing pain relief and improved mobility. However, inaccurate acetabular cup positioning can lead to complications such as dislocation, impingement, wear, and aseptic loosening. The Lewinnek safe zone (inclination 40° ± 10°, anteversion 15° ± 10°) serves as a guideline, but achieving consistent placement with freehand techniques is challenging due to anatomical variability, pelvic tilt, and surgical factors.[1,2]

Advanced methods like navigation and robotic systems improve accuracy but are costly and less feasible in resource-limited settings. Anatomical landmarks such as the transverse acetabular ligament (TAL), acetabular notch, and rim offer a simple, patient-specific alternative. These have shown good reliability in achieving safe cup orientation without additional equipment.[3,4]

In India, variations in anatomy and higher rates of secondary arthritis make such techniques particularly relevant. This prospective study evaluates the accuracy and early outcomes of landmark-guided acetabular cup positioning in primary THA at a tertiary care center in Mumbai, aiming to assess its feasibility, reproducibility, and suitability as a cost-effective alternative.

Materials and Methods

This prospective observational study was conducted in orthopedic department at a tertiary care teaching center

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DOI:
10.21276/amit.2026.v13.i2.656

How to cite this article: Tiwary BK, Chandak P, Chaturvedi A, Pradhan SS, Karak A, Singh N. A Prospective Study on Acetabular Cup Positioning Using Anatomical Landmarks in Primary Total Hip Arthroplasty at a Tertiary Care Center in Mumbai. Acta Med Int. 2026;13(2):112-115.

(Mumbai) over one year. The study included adult patients (age 18–80 years) undergoing primary uncemented THA for osteoarthritis, avascular necrosis, or post-traumatic arthritis. All surgeries were performed by a single senior surgeon with over 15 years of experience in joint replacement to minimize inter-surgeon variability. The institutional ethics committee approved the protocol, and written informed consent was obtained from every participant in accordance with the Declaration of Helsinki. Patients with revision THA, active infection, severe bone loss requiring augments, or contraindications to standard radiography/CT were excluded. Inclusion criteria encompassed patients with adequate bone stock for uncemented fixation and willingness for postoperative imaging and follow-up. Exclusion criteria included neuromuscular disorders affecting gait, bilateral simultaneous procedures, or pelvic deformities precluding reliable landmark identification. Preoperative evaluation involved clinical assessment, Harris Hip Score (HHS), and standard radiographs; CT was used selectively for complex cases.

Surgical technique involved a posterolateral approach in the lateral decubitus position. After capsulotomy and femoral head removal, the acetabulum was reamed progressively. Cup positioning relied on anatomical landmarks: the transverse acetabular ligament (TAL) served as the primary reference for anteversion by aligning the inferior cup rim parallel to it, while inclination was guided by placing the cup between superior and inferior reference points opposite the transverse acetabular notch (target ~40° abduction). Additional rim points (anterior at acetabular notch and posterior opposite) assisted fine adjustment. Press-fit fixation followed, with screws as needed. Intraoperative trial reduction confirmed stability across full range of motion. Standard postoperative protocol included early mobilization, thromboprophylaxis, and antibiotics.

Postoperative radiographic evaluation was performed within two weeks using standardized AP pelvis views (patient supine, beam centered on pubis). Cup inclination was measured as the angle between the cup axis and the trans-ischial line; anteversion used the modified Murray method on AP radiographs or CT where available (angle between cup plane and inter-teardrop line). Measurements were performed independently by two observers, with inter-observer reliability assessed via intraclass correlation coefficient (>0.90). Outliers were defined as inclination <30° or >50°, anteversion <5° or >25° (Lewinnek criteria). Functional assessment used HHS at 6 weeks and 3 months.

Data were entered into Microsoft Excel and analyzed using SPSS version 26. Descriptive statistics (mean ± SD, ranges, percentages) summarized continuous and categorical variables. Paired t-tests compared pre- and postoperative scores. A p-value <0.05 was considered significant. No sample size calculation was performed as this was an exploratory prospective series aiming for at least 50 hips based on similar prior studies.

Results

A total of 50 patients (52 hips; 2 bilateral) were included, with mean age 58.4 ± 9.2 years (range 32–78), 62% male, and mean BMI 26.8 ± 4.1 kg/m². Primary indications were avascular necrosis (48%), osteoarthritis (42%), and post-traumatic (10%). Mean preoperative HHS was 42.6 ± 8.4.

Table 1: Demographic and Preoperative Characteristics (n=50 patients, 52 hips)

Parameter	Value (Mean ± SD or n (%))
Age (years)	58.4 ± 9.2
Gender (Male/Female)	31 (62%)/19 (38%)
BMI (kg/m²)	26.8 ± 4.1
Indication: AVN/OA/Trauma	25/22/5
Preoperative HHS	42.6 ± 8.4

Table 2: Radiographic Cup Positioning Parameters (n=52 hips)

Parameter	Mean ± SD (Range)	Within Safe Zone n (%)
Inclination (°)	41.2 ± 4.8 (32–52)	49 (94%)
Anteversion (°)	16.8 ± 5.2 (6–28)	47 (90%)
Combined Safe Zone	-	46 (88%)

Table 3: Outlier Analysis and Associated Factors

Outlier Type	n (%)	Associated Factors
Inclination only	2 (3.8%)	Obesity (BMI>30), dysplasia
Anteversion only	3 (5.8%)	Severe anteversion deformity
Both	1 (1.9%)	Technical (early case)
Total Outliers	6 parameters in 4 hips	-

Table 4: Functional Outcomes and Complications

Outcome	Preoperative	3 Months	p-value
Mean HHS	42.6 ± 8.4	88.4 ± 6.2	<0.001
Dislocation	-	0	-
Other complications	-	2 transient nerve palsy	-

Mean surgical time was 78 ± 12 minutes. All cups achieved initial press-fit stability. At 3-month follow-up, no dislocations or revisions occurred, and patients reported high satisfaction with improved mobility.

Discussion

Accurate acetabular cup positioning is fundamental to the long-term success of total hip arthroplasty, influencing stability, wear characteristics, and patient satisfaction. This prospective study from a Mumbai tertiary center demonstrated that a straightforward technique relying on anatomical landmarks—primarily the transverse acetabular ligament for anteversion and combined notch/rim references for inclination—achieved 88% placement within the classic Lewinnek safe zone. These findings align with the growing recognition that patient-specific bony and ligamentous references can provide reliable guidance without sophisticated navigation, especially in routine primary cases.[5,6]

The mean inclination of 41.2° ± 4.8° in our series closely mirrors results from similar landmark-based prospective studies. For instance, an Indian observational study on 30 primary THRs using posterior approach and anatomical landmarks reported comparable inclination values with good functional correlation. Internationally, Ha et al. (2012) in a cohort using anatomic rim points achieved high accuracy with low dislocation, supporting our 94% safe-zone rate for inclination. Nguyen et al. (2025) in a Vietnamese prospective series using TAL found mean acetabular inclination around 41.9°, nearly identical to ours, with strong correlations to native anatomy.[7,8]

For anteversion, our mean of 16.8° ± 5.2° with 90% within 5°–25° compares favorably to literature. Archbold and colleagues reported dramatically reduced dislocation (0.6%) when cups were aligned parallel to the TAL, emphasizing its reliability as a version guide—consistent with our low outlier rate. A 2025 Cureus prospective study on TAL-guided positioning in primary THA echoed this, noting optimal anteversion between 5°–25° in most cases. In contrast, some studies highlight variability in arthritic hips; Abe et al. noted TAL as reliable in osteonecrosis but less so in advanced osteoarthritis, which may explain the few anteversion outliers in our AVN-heavy cohort. Indian data from Deep et al. on TAL orientation in arthritic hips showed average anteversion near 10°–12°, aligning with our intraoperative adjustments.[9]

Functional outcomes further validated the technique. The significant HHS improvement to 88.4 at 3 months, with zero dislocations, mirrors international benchmarks where landmark accuracy correlated with stability. Singh et al. (2025) in an Indian prospective series linked cup positioning within safe zones to better early scores, similar to our results. Limitations of navigation (cost, learning curve) make landmark methods particularly relevant in Indian tertiary settings, where our outlier rate (7.7% combined) was lower than many freehand historical controls (up to 20–40% outliers).[10,11]

Comparison with technology-assisted studies reinforces the value of simplicity. Robotic or navigated series often report errors <3°, yet our landmark errors remained clinically acceptable (<5° mean deviation implied), with no added radiation or time burden. Studies like those from Vietnam and Korea using TAL or rim landmarks achieved 80–96% safe-zone compliance, paralleling our 88%. Differences may stem from patient factors (higher BMI or dysplasia in outliers) or measurement methods (radiographic vs. CT).[12]

This approach promotes anatomical restoration tailored to individual pelvic morphology, a key advantage in diverse Indian populations. However, challenges persist in severe deformities where landmarks may be distorted.[13]

The study has a relatively small sample size from a single center and short-term follow-up (3 months), limiting generalizability to long-term wear or late dislocations. Radiographic measurements, while standardized, carry inherent pelvic tilt variability compared to CT gold standard in all cases. Selection bias toward a single surgeon may overestimate reproducibility in less experienced hands. Future multicenter trials with longer follow-up and CT validation are recommended.

Conclusion

This prospective study demonstrates that anatomical landmark-guided acetabular cup positioning using the transverse acetabular ligament and acetabular notch/rim is a reliable, reproducible, and cost-effective technique in primary total hip arthroplasty. At our Mumbai tertiary center, 88% of cups were within the Lewinnek safe zone, with excellent early functional outcomes and no dislocations. These findings support its routine use, especially in resource-limited settings where navigation is unavailable. By relying on patient-specific anatomy, surgeons can improve consistency and reduce complications without added complexity. Although long-term follow-up is required, this study supports landmark-based positioning as a safe and practical standard for most primary THA cases, contributing valuable Indian data to global literature.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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