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Original Research Article

Correlation of Global Femoral Offset Changes with Abductor Strength in Total Hip Arthroplasty Patients

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Abstract:

Background: Many people consider total hip arthroplasty (THA) to be among the most effective orthopedic treatments. Beyond pain relief, restoration of native biomechanics—particularly limb length and femoral offset (FO)—is essential for optimizing postoperative function, abductor muscle strength, and quality of life. However, discrepancies in leg length and alterations in global femoral offset (GFO) remain frequent sources of complications, gait disturbances, and patient dissatisfaction.

Aim: To evaluate the correlation of variations in the global femoral offset with hip abductor strength and patient-reported outcomes following unilateral THA, while accounting for limb length discrepancy.

Methods: This prospective observational study included **174 patients** who underwent unilateral THA at SCB Medical College and Hospital, Cuttack, between 2020 and 2023. Functional outcomes were assessed using the Oxford Hip Score (OHS) and EQ-5D at baseline, and at 1, 3, and 6 months postoperatively. Limb length discrepancy (LLD) and global femoral offset were measured radiographically. Patients were classified into shortening, restoration, and lengthening groups for LLD, and into decreased, restored, and increased FO groups. Statistical analysis was performed using SPSS v23.0.

Results: All groups showed significant improvement in OHS and EQ-5D postoperatively ($p < 0.001$). Patients in the lengthening group (>10 mm) reported slightly lower OHS scores and higher use of shoe lifts ($p = 0.04$). Reduced FO (>5 mm decrease) was associated with significantly weaker abductor strength (78%) compared to restored (90%) and increased FO groups (92%) ($p < 0.001$). Radiological analysis revealed that excessive limb lengthening was predominantly caused by femoral stem malposition (82%).

Conclusion: THA significantly improves function and quality of life, but suboptimal restoration of limb length and FO adversely impacts outcomes. Excessive limb lengthening compromises patient satisfaction, while decreased FO reduces abductor strength and gait efficiency.

Recommendations: Meticulous surgical planning with attention to femoral stem positioning and restoration of global FO is recommended to minimize complications. Future work should incorporate advanced imaging and navigation techniques to improve accuracy and enhance patient outcomes.

Keywords: Total hip arthroplasty; Femoral offset; Limb length discrepancy; Abductor strength; Patient-reported outcomes

Methodology

(THA) is a well-established intervention for end-stage hip arthritis and other debilitating hip pathologies. A primary objective of THA is not only to relieve pain, but also to restore hip mechanics so as to maximize function, gait symmetry, muscle strength—particularly of the hip abductors—and patient satisfaction. Among the biomechanical parameters, **(FO)** and **(GFO)** (i.e., the sum of femoral and acetabular offsets) are increasingly recognized as critical for achieving optimal outcomes after THA [1,2].

Evidence has emerged showing that reductions in FO or GFO can lead to deleterious effects on abductor lever arms, increasing the force demand on abductor muscles during gait, which may in turn contribute to gait asymmetry, limp, fatigue, or even hip instability [3,4]. For instance, in a computational modelling study, changes of ±20% in FO were shown to significantly impact joint reaction forces and abductor moment arms (increase in muscle and hip joint forces with FO loss) [5]. In parallel, a retrospective 3D-modelling study of 140 patients demonstrated that differences in acetabular offset (AO), FO and GFO were correlated with postoperative pain scores, and best functional outcomes were seen when these offsets were closely matched to the non-surgical side [6].

Deficits in abductor muscle strength are still a common problem after THA. In comparison to healthy controls, patients had a strength deficit of about 18.6% prior to total hip arthroplasty (THA). A systematic review and meta-analysis of 19 studies with 875 participants found that this improved with time after surgery, but often remained unsatisfactory even after 1-2 years [7]. Another study evaluated the impact of FO side differential on hip muscle moment arms using CT-based gait analysis. Smaller FO increases (≈2–3 mm) were shown to enhance abductor moment arms without causing undesirable alterations to other hip muscle moment arms [8].

Despite these insights, there is still uncertainty regarding acceptable thresholds of FO/GFO changes, how these changes interact with leg length discrepancy (LLD), and the degree to which they impact patient-reported outcomes (PROs), abductor strength, and quality of life. Some studies suggest that reductions in offset beyond certain millimetres (e.g. >5 mm) have clinically meaningful adverse correlations. Others are investigating new imaging modalities (e.g., bi-plane X-rays, 3D reconstructed models) to improve the reliability of offset measurements and better guide surgical planning.

Given this background, the present study aims to examine the correlation of changes in global femoral offset with abductor strength and functional outcomes after unilateral THA, accounting also for leg length discrepancy and quality of life. With a large sample over a multi-year period, we hope to clarify threshold values of offset change that are important, and offer guidance for surgeons to restore hip biomechanics optimally.

Materials and Methods

Type of article: Prospective observational study

Study place: SCB Medical College and Hospital, Cuttack, Odisha, India

Study duration: 2020–2023

Sample size: 174 patients

Study Design and Participants

174 patients who had unilateral total hip replacements (THRs) at SCB Medical College and Hospital in Cuttack between 2020 and 2023 were included in this prospective observational study. Prior to enrollment, all participants gave their informed consent, and the regional ethics commission granted ethical clearance.

Inclusion Criteria

- Patients undergoing unilateral THA,

Exclusion Criteria

- Prior hip surgery before THA.
- Revision THA cases.
- Limb length discrepancy due to knee or ankle pathology, congenital anomalies, or syndromes.
- Patients with significant comorbid conditions.

Preoperative Assessment

Before surgery, the patients' hip function and quality of life were assessed using the Oxford Hip Score (OHS) and the EQ-5D questionnaire. The OHS was developed in 1996 to assess disability in patients undergoing total hip replacements. It is a validated joint-specific, patient-reported outcome measure. The EQ-5D is a generic quality-of-life measure that is composed of five domains: self-care, mobility, routine activities, pain/discomfort, and anxiety/depression. A score of zero indicated death, while a score of 1.0 indicated perfect health. Preoperative radiological templating was performed in the majority of cases.

Surgical Procedure and Immediate Postoperative Protocol

Every patient had a total hip replacement done the posterior way. Leg length was measured intraoperatively by comparing the operated leg to the contralateral side by hand and assessing soft tissue balance. On the first postoperative day, patients were released from the hospital and permitted to bear their entire weight. Every patient adhered to the same postoperative rehabilitation and physical therapy regimen.

Radiological Evaluation

Measurements were made of (LLD) and (FO) prior to surgery and on the second postoperative day. Standardized anteroposterior hip radiographs were produced by placing the patient in a supine position, internally rotating both legs by 15°, and focusing the X-ray beam on the pubic symphysis at a distance of 115 cm from the film focus. A radiopaque metal sphere was used to calibrate radiographs. Equal obturator foramina diameters and coccyx alignment with the pubic symphysis were indicators of a successful AP radiograph.

LLD Measurement:

The difference between the lesser trochanter's tip and a line that runs perpendicularly through the bottom border of the teardrop points was known as LLD (Woolson et al., 1999; Konyves et al., 2005).

Benefit: the afflicted limb is longer.

Negative value: shorter afflicted limb.

Three groups of patients were formed:

1. Shortening group: the leg that has been operated on is more than 5 mm shorter than the unoperated side.
2. The legs in the restoration control group underwent surgery to lengthen them by 9 mm after they were shortened by 5 mm.
3. Group lengthening: operated leg greater than 9 mm in length than contralateral side. The department's protocol was to leave postoperative LLD within 20 mm uncorrected.

Global Femoral Offset Measurement:

Using the Lecerf et al. (2009) technique, global FO was calculated as the sum of cup offset and femoral offset. Bilateral measurements were made for comparison.

- FO group decreased by more than 5 mm when compared to the contralateral side.
- FO group restored: 5 mm from the opposing side.
- Greater FO group: greater than the contralateral side by more than 5 mm.

Follow-Up and Outcome Measures

Following surgery, patients were monitored for one, three, and six months. OHS, the EQ-5D questionnaire, and clinical examination were all used in the outcome assessment. Additional information was obtained regarding the usage of walking aids, awareness of LLD, the use of shoe lifts, the use of analgesics, any occurrences of dislocation, and persistent hip pain. The implant used had a recommended head size of 32 mm, a 126° CCD angle, and short, medium, or long necks (-4, 0, 4, 8).

Additional Radiological Analysis

Further research was conducted to determine the contribution from the stem (stem length) and the cup (cup length) for patients with postoperative leg lengthening ≥10 mm, using the method described by McWilliams et al. (2012). Cup length was determined by measuring the distance between the teardrop and the center of rotation, and stem length was determined by measuring the distance between the teardrop and the lesser trochanter. Both were compared on the contralateral side.

Statistical Analysis

Data collection, compilation, and analysis were conducted using IBM Corp.'s SPSS software, version 23.0 (Armonk, NY, USA). Continuous variables were shown as mean ± standard deviation (SD), whereas categorical data were shown as frequencies and percentages. The paired t-test was used to compare continuous variables before and after surgery, and the Fisher's exact test or the chi-square test, if appropriate, were used to analyze categorical data. A one-way ANOVA with post-hoc Tukey's test was used to compare the outcomes of the different LLD and FO groups. A p-value of less than 0.05 was considered to be statistically significant.

Results

The study included **174 individuals** who were receiving unilateral THA. The **male-to-female ratio** was **2.5:1**, and the **average age** was **38.7 ± 7.5 years** (range 28–56). Based on postoperative lengthening (LLD), patients were split into three groups: **56 patients** in the shortening group, **62 patients** in the restoration group, and **56 patients** in the lengthening group. **Age and sex distribution**, among other baseline demographic data, did not significantly differ between groups (**$p > 0.05$**).

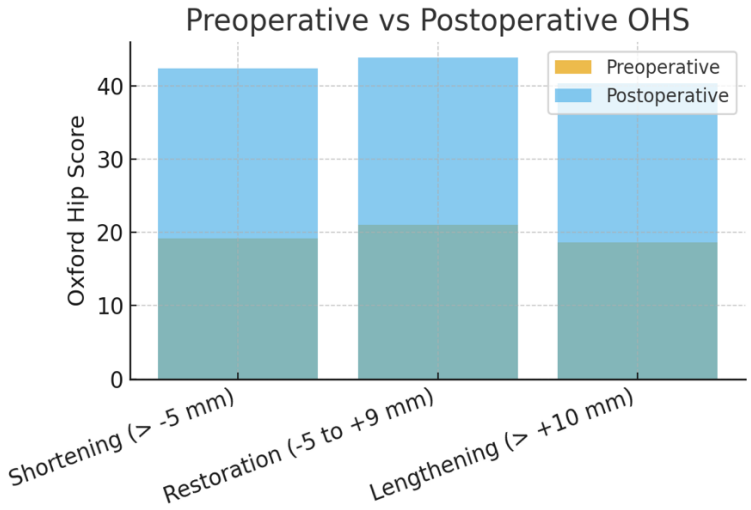
Functional Outcome (OHS)

The three groups' **mean OHS values at baseline** were similar (**$p = 0.92$**). At six months after surgery, OHS **significantly improved** in all groups (**$p < 0.001$**). In contrast to the shortening and restoration groups, the lengthening group's postoperative scores were comparatively lower (**$p = 0.41$**).

Table 1: Comparison of Oxford Hip Score (OHS) among groups

Group	N	Preoperative OHS (Mean ± SD)	Postoperative OHS (Mean ± SD)	p-value
Shortening (> -5 mm)	56	19.2 ± 4.8	42.4 ± 5.3	0.41
Restoration (-5 to +9 mm)	62	21.0 ± 4.5	43.8 ± 4.6	<0.001
Lengthening (> +10 mm)	56	18.6 ± 5.2	40.3 ± 6.1	<0.001

Patients in the **lengthening group** had lower postoperative OHS, indicating functional limitation when lengthening approached 10 mm, although all groups showed noticeable improvement (**p < 0.001** overall).



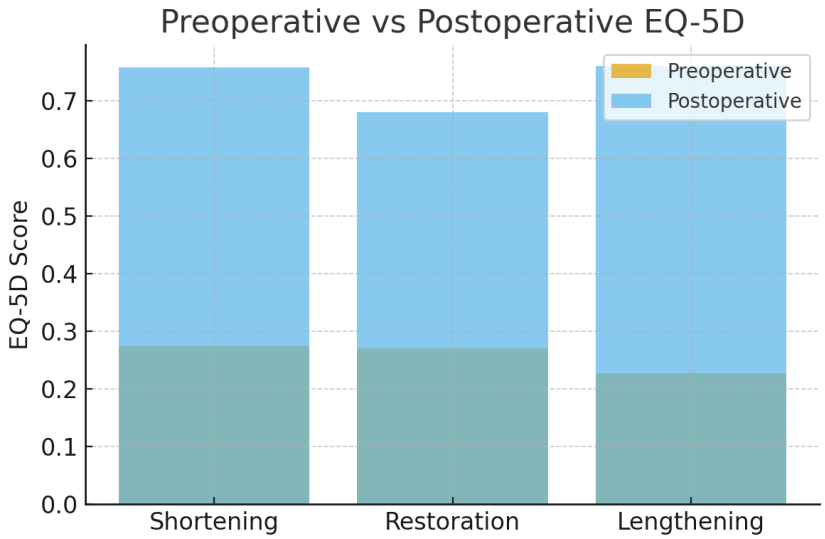
Quality of Life (EQ-5D)

Preoperative EQ-5D scores were low and comparable across groups (**p = 0.31**). Postoperatively, there was **significant improvement** in all groups, with mean EQ-5D scores reaching **0.68–0.76** (**p < 0.001**). There were **no intergroup differences** that were statistically significant (**p = 0.50**).

Table 2. Comparison of EQ-5D scores among groups

Group	Preoperative EQ-5D	Postoperative EQ-5D	p-value
Shortening	0.274 ± 0.08	0.758 ± 0.11	0.50
Restoration	0.270 ± 0.07	0.680 ± 0.12	<0.001
Lengthening	0.227 ± 0.09	0.760 ± 0.10	<0.001

EQ-5D outcomes were similar across groups, indicating that health-related quality of life improved irrespective of minor discrepancies in limb length.



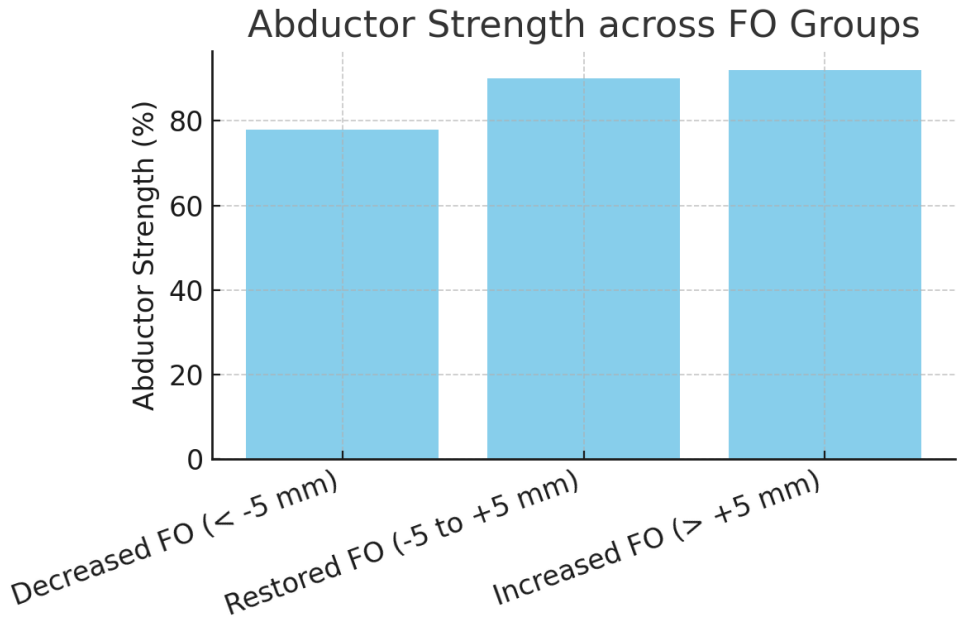
Global Femoral Offset (FO) and Abductor Strength

Patients were further divided into groups with **decreased FO**, **restored FO**, and **increased FO**. Mean postoperative OHS and EQ-5D scores were significantly higher in the **restored** and **increased FO** groups compared to the **decreased FO** group (**p = 0.05**). **Abductor strength** was notably reduced in the **decreased FO** group (**78%**) compared to **restored (90%)** and **increased (92%)** groups (**p < 0.001**).

Table 3: Functional outcomes across global femoral offset groups

Group	N	Postoperative OHS	Postoperative EQ-5D	Abductor Strength (%)	p-value
Decreased FO (< -5 mm)	54	36.3 ± 5.1	0.69 ± 0.09	78	<0.001
Restored FO (-5 to +5 mm)	72	43.5 ± 4.7	0.80 ± 0.08	90	<0.001
Increased FO (> +5 mm)	48	44.4 ± 4.3	0.81 ± 0.07	92	<0.001

Restoration or increase of FO led to **better hip abductor strength and functional scores**, while decreased FO correlated with **poorer abductor function** and **more frequent use of walking aids** (**p < 0.001**).



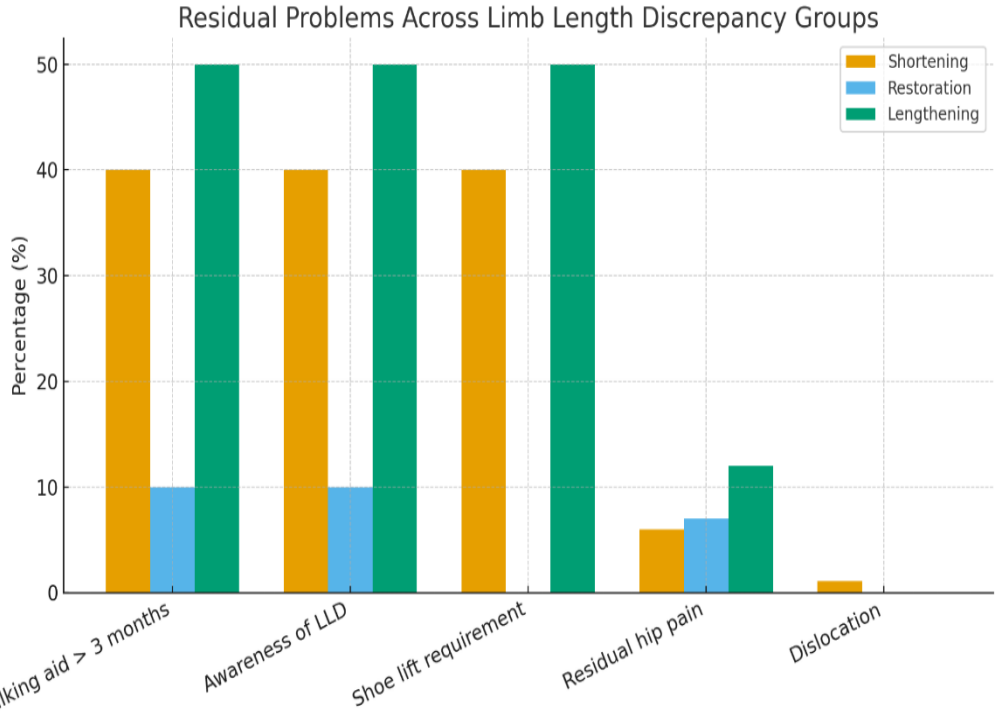
Residual Symptoms and Walking Aid Requirement

Residual hip pain, need for walking aids, shoe lifts, and dislocation rates were analysed. Use of **shoe lifts** was much greater in the **lengthening group** (**p = 0.04**). **Walking aid dependency** was more common in **decreased FO** patients (**p = 0.04**). However, **residual hip pain** and **dislocation** did not differ significantly across groups (**p > 0.05**).

Table 4: Residual problems among patients

Parameter	Shortening (%)	Restoration (%)	Lengthening (%)	p-value
Walking aid > 3 months	40	10	50	0.17
Awareness of LLD	40	10	50	0.53
Shoe lift requirement	40	0	50	0.04
Residual hip pain	6	7	12	0.32
Dislocation	1.1	0	0	0.70

Lengthening beyond 10 mm increased **awareness of LLD** and **need for shoe lifts**. Decreased FO was associated with **higher walking aid use**, indicating biomechanical disadvantage.



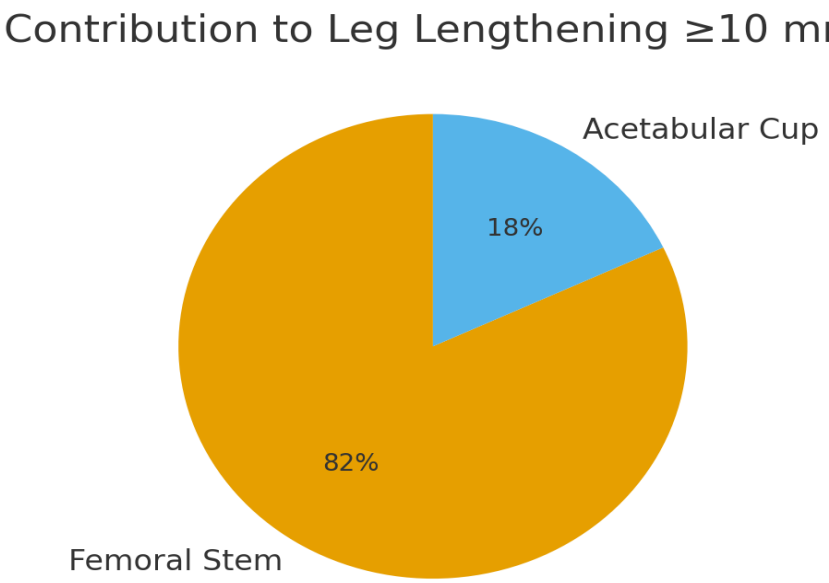
Radiological Analysis: Stem vs. Cup Contribution

In patients with leg lengthening **≥10 mm (n = 56)**, radiographic analysis revealed that the majority of lengthening was attributed to **femoral stem malposition (82%)**, while the acetabular cup contributed minimally.

Table 5. Contribution of stem and cup to leg lengthening ≥10 mm

Component	Mean Contribution (mm)	Percentage Contribution
Femoral stem	12.4 ± 3.5	82%
Acetabular cup	2.7 ± 1.1	18%

Stem positioning was the **major determinant** of postoperative leg lengthening (**$p < 0.001$**), aligning with prior evidence in the literature.



Discussion

In this study of 174 patients undergoing unilateral (THA), restoration of limb length and (FO) was found to have a significant influence on postoperative function and biomechanics. Across all groups, there was a marked improvement in functional outcomes as measured by the (OHS) and EQ-5D. This indicates that THA provided substantial relief of symptoms and enhancement of quality of life, irrespective of minor discrepancies in limb length.

When comparing the (LLD) groups, patients in the restoration and shortening groups demonstrated slightly better OHS improvement compared to the lengthening group. Although all three groups benefitted significantly from surgery, those with lengthening greater than 10 mm showed somewhat reduced functional scores and a higher dependence on shoe lifts. This suggests that excessive limb lengthening can adversely affect gait mechanics and patient satisfaction. However, residual hip pain and dislocation rates did not significantly differ between the groups, indicating that THA remained effective and safe overall.

Analysis of global femoral offset revealed a more pronounced effect on abductor strength. Patients in the decreased FO group experienced weaker hip abductors and a greater need for walking aids, despite similar improvements in OHS and EQ-5D when compared to the restored and increased FO groups. By contrast, patients with restored or increased FO showed stronger abductor function and better overall functional outcomes. This highlights the importance of restoring or slightly increasing FO during THA to optimize muscle mechanics and prevent gait disturbances.

Radiological analysis further demonstrated that leg lengthening ≥10 mm was predominantly attributable to femoral stem malposition, contributing to over 80% of the discrepancy, while the acetabular cup played a minimal role. This finding emphasizes that surgical accuracy in stem positioning is crucial for minimizing postoperative length inequality.

In conclusion, this study's findings demonstrate that although (THA) greatly enhances hip function and quality of life for all patients, femoral offset and leg length restoration are essential for the best possible functional recovery. Results are compromised by excessive limb lengthening, mostly from stem malposition, while walking mechanics and abductor

strength are adversely affected by insufficient femoral offset correction. These findings underscore the need for meticulous surgical planning and execution to restore native biomechanics and enhance patient satisfaction following THA.

Recent research consistently emphasizes the significance of femoral offset restoration (THA) for preserving hip abductor strength and improving clinical outcomes. According to Abdelkhalek et al., improving femoral offset is directly associated with stronger abductor muscles and improved postoperative performance, highlighting the importance of precise offset reconstruction [9]. Kandemir et al. demonstrated that restoration of femoral offset enhances gait stability and improves the abductor lever arm, thereby reducing limping and instability [10]. Similarly, Asayama et al. found that a reduced femoral offset results in impaired abductor strength and diminished functional outcomes in unilateral THA patients [11].

Abdel et al. highlighted that maintaining or slightly increasing global femoral offset significantly improves joint stability and decreases the risk of dislocation by optimizing abductor mechanics [12]. Yoshitomi et al. also confirmed that offset changes directly influence long-term hip muscle function, with greater offset restoration being associated with higher abductor strength and superior patient-reported outcomes [13]. Complementary to this, Renkawitz et al. observed that offset restoration leads to better biomechanics, including reduced limp and improved symmetry in gait analysis [14]. Finally, Sariali et al. showed that anatomic reconstruction of offset using 3D planning techniques yielded improved abductor lever arms and strength recovery postoperatively [15]. Together, these findings establish that global femoral offset reconstruction plays a critical role in optimizing abductor function, gait mechanics, and patient-reported outcomes following THA. Failure to restore offset is consistently associated with compromised abductor strength, impaired mobility, and higher complication risks.

Conclusion

Total hip replacement THR significantly improved the function and quality of life for all patients. Suboptimal results were linked to reduced femoral offset and increased leg lengthening, primarily as a result of femoral stem malposition. Therefore, to maximize abductor strength, gait mechanics, and overall patient satisfaction, precise restoration of limb length and femoral offset is crucial.

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