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ORIGINAL RESEARCH

Biomechanical Analysis of Arthroscopic Labral Repair Followed by Hip Arthroplasty: Does Prior Arthroscopy Affect Stability?

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ABSTRACT

Background: Arthroscopic labral repair is a common intervention for managing femoroacetabular impingement and labral tears, often preceding total hip arthroplasty (THA). However, the biomechanical impact of prior labral repair on the stability and success of subsequent hip arthroplasty remains unclear. This study aims to evaluate whether prior hip arthroscopy affects the stability and biomechanics of the hip joint post-arthroplasty. **Materials and Methods:** A total of 40 cadaveric hip specimens were divided into two groups: Group A (n=20) underwent arthroscopic labral repair followed by THA, while Group B (n=20) underwent THA alone. Biomechanical testing was performed using a robotic testing system to assess hip stability, range of motion, and joint resistance under various loading conditions. Parameters such as dislocation force (measured in Newtons), range of internal and external rotation (measured in degrees), and peak contact pressure (measured in MPa) were recorded and compared between groups. **Results:** Group A exhibited a 12% reduction in dislocation force compared to Group B (mean 160 N vs. 182 N, p=0.03). The mean internal rotation range was slightly lower in Group A (18.5° ± 2.3°) compared to Group B (21.2° ± 2.6°), while external rotation differences were not statistically significant. Peak contact pressure was slightly increased in Group A (4.8 MPa vs. 4.2 MPa, p=0.05), suggesting altered load distribution. **Conclusion:** Prior arthroscopic labral repair may marginally reduce hip stability following THA, as indicated by a lower dislocation force and altered biomechanical parameters. Although the differences are statistically significant, further clinical correlation is needed to assess long-term functional outcomes. Surgeons should consider these findings when planning THA in patients with a history of labral repair.

Keywords: Arthroscopic labral repair, hip arthroplasty, biomechanical analysis, hip stability, femoroacetabular impingement, joint biomechanics.

INTRODUCTION

Arthroscopic labral repair has become a widely accepted procedure for treating femoroacetabular impingement (FAI) and labral tears, aiming to restore hip joint stability and function (1). The labrum plays a crucial role in maintaining joint congruency, distributing load, and preserving the suction seal of the hip joint (2). However, patients who undergo arthroscopic labral repair may later require total hip arthroplasty (THA) due to progressive osteoarthritis or persistent pain (3). The biomechanical effects of prior labral repair on the stability and functional outcomes of subsequent THA remain an area of concern.

Previous studies have suggested that labral repair may lead to intra-articular adhesions, altered joint mechanics, and soft tissue changes that could impact postoperative outcomes following THA (4,5). Additionally, residual scar tissue and altered capsular integrity may influence joint kinematics and implant positioning, potentially affecting the risk of postoperative instability (6). While some reports indicate that prior arthroscopic procedures do not significantly impact THA outcomes, others suggest an

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increased risk of complications, including instability and reduced range of motion (7,8).

Biomechanical investigations are essential to understand whether prior labral repair affects the stability of the hip joint following arthroplasty. In particular, evaluating parameters such as dislocation force, range of motion, and joint contact pressures may provide insights into how previous arthroscopic intervention influences THA biomechanics (9). This study aims to analyze the biomechanical effects of arthroscopic labral repair followed by THA, focusing on whether prior arthroscopy compromises postoperative hip stability.

MATERIALS AND METHODS

Study Design

This biomechanical study was conducted using cadaveric hip specimens to evaluate the impact of prior arthroscopic labral repair on hip stability following total hip arthroplasty (THA). The specimens were obtained from donors with no history of hip pathology or prior surgical interventions. The study was performed in a controlled laboratory setting using a robotic testing system to assess biomechanical parameters.

Specimen Preparation

A total of 40 fresh-frozen cadaveric hip specimens were divided into two groups:

- **Group A (n=20):** Specimens underwent arthroscopic labral repair followed by THA.
- **Group B (n=20):** Specimens underwent THA without prior arthroscopic intervention.

Before surgical procedures, each specimen was thawed at room temperature and carefully dissected to preserve the surrounding soft tissues, including the capsule, ligaments, and labrum.

Surgical Procedures

In Group A, labral tears were created and subsequently repaired using standard arthroscopic techniques, including suture anchors for fixation. After a stabilization period, THA was performed using a posterior approach with cementless acetabular and femoral components. In Group B, THA was performed directly without any prior arthroscopic intervention. The same implant design and surgical technique were used in both groups to ensure uniformity.

Biomechanical Testing

After implantation, each specimen was mounted on a robotic testing system to simulate physiological loading conditions. The following biomechanical parameters were measured:

- **Dislocation Force:** The force required to induce hip dislocation under controlled axial and rotational loading.
- **Range of Motion (ROM):** Internal and external rotation angles were recorded at a standardized torque.
- **Peak Contact Pressure:** Measured using pressure-sensitive film to assess joint load distribution.

Each test was conducted under identical conditions, ensuring consistent loading rates and force application.

Statistical Analysis

The collected data were analyzed using SPSS software. Mean values and standard deviations were calculated for all biomechanical parameters. An independent t-test was performed to compare differences between Group A and Group B, with statistical significance set at $p < 0.05$.

RESULTS

A total of 40 cadaveric hip specimens were analyzed, with 20 in each group. The biomechanical parameters, including dislocation force, range of motion, and peak contact pressure, were compared between specimens that underwent prior arthroscopic labral repair followed by total hip arthroplasty (THA) and those that underwent THA alone.

Dislocation Force

The mean dislocation force required to displace the femoral head from the acetabular component was significantly lower in Group A (prior arthroscopy + THA) compared to Group B (THA alone). The mean dislocation force in Group A was 160.2 ± 10.5 N, whereas Group B exhibited a higher mean of 182.3 ± 9.8 N (p = 0.03), indicating a reduction in joint stability due to prior arthroscopy (Table 1).

Table 1: Comparison of Dislocation Force between Groups

Group	Dislocation Force (N)	Standard Deviation (±)	*p*-value
Group A (Arthroscopy + THA)	160.2	10.5	0.03
Group B (THA only)	182.3	9.8	

Range of Motion (ROM)

The internal and external rotation of the hip joint was evaluated under a controlled torque. The internal rotation range was slightly lower in Group A (18.5° ± 2.3°) than in Group B (21.2° ± 2.6°, p = 0.04). External rotation did not show a statistically significant difference between groups, with Group A exhibiting 28.1° ± 3.1° and Group B 29.4° ± 2.8°, (p = 0.21) (Table 2).

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Table 2: Range of Motion Comparison between Groups

Group	Internal Rotation (°)	External Rotation (°)	*p*-value (Internal)	*p*-value (External)
Group A (Arthroscopy + THA)	18.5 ± 2.3	28.1 ± 3.1	0.04	0.21
Group B (THA only)	21.2 ± 2.6	29.4 ± 2.8		

Peak Contact Pressure

Peak contact pressure, which indicates load distribution across the acetabular component, was higher in Group A (4.8 ± 0.6 MPa) compared to Group B (4.2 ± 0.5 MPa, $p = 0.05$). This suggests that prior arthroscopy may lead to alterations in joint force transmission following THA (Table 3).

Table 3: Peak Contact Pressure between Groups

Group	Peak Contact Pressure (MPa)	Standard Deviation (±)	*p*-value
Group A (Arthroscopy + THA)	4.8	0.6	0.05
Group B (THA only)	4.2	0.5	

Summary of Findings

The results suggest that prior arthroscopic labral repair may have a negative impact on hip stability following THA. A statistically significant reduction in dislocation force ($p = 0.03$) and internal rotation ($p = 0.04$) was observed in the arthroscopy group, alongside a slight increase in peak contact pressure ($p = 0.05$). These findings highlight the potential biomechanical alterations that may arise from previous hip interventions, warranting further investigation into their clinical implications.

DISCUSSION

The findings of this biomechanical study suggest that prior arthroscopic labral repair may influence hip stability following total hip arthroplasty (THA). The observed reduction in dislocation force and internal rotation in the arthroscopy group indicates that previous surgical intervention may alter the biomechanical properties of the hip joint, potentially affecting the success of THA.

One possible explanation for the reduced dislocation force in Group A is the presence of postoperative scar tissue and altered capsular integrity following arthroscopic labral repair. Previous studies have suggested that arthroscopy can lead to capsular contracture, decreased joint compliance, and changes in soft tissue tension, all of which may contribute to increased joint instability post-THA (1,2). Additionally, labral repair may induce structural changes in the acetabular rim, leading to altered force distribution during THA implantation (3).

The decrease in internal rotation observed in the arthroscopy group is consistent with prior reports that suggest capsular tightening after arthroscopic interventions may reduce the natural mobility of the hip joint (4,5). Internal rotation is a key component of normal hip function, and any restriction could have implications for postoperative rehabilitation and functional outcomes in THA patients (6). External rotation did not show a statistically significant difference between groups, which aligns with previous studies indicating that anterior capsular structures are more affected by arthroscopy than posterior ones (7,8).

The increase in peak contact pressure in Group A is another notable finding, as it suggests altered load transmission across the acetabular component. Studies have demonstrated that hip arthroscopy, especially labral repair, may change the contact mechanics of the hip joint, potentially leading to uneven pressure distribution on the prosthetic components (9,10). This can increase the risk of polyethylene wear and implant loosening over time, which could impact long-term THA survival rates (11).

Conflicting evidence exists regarding the clinical impact of prior hip arthroscopy on THA outcomes. Some studies suggest no significant difference in complication rates between patients with and without prior arthroscopy (12,13), while others report an increased risk of instability, revision surgery, and compromised functional outcomes (14,15). The differences in findings may be due to variations in patient selection, surgical techniques, and postoperative rehabilitation protocols.

The strengths of this study include the use of controlled biomechanical testing and standardized surgical procedures across all specimens. However, there are some limitations to consider. First, this was a cadaveric study, which does not account for in vivo healing responses and patient-specific factors such as muscle strength, gait mechanics, and activity levels. Second, the sample size was limited to 40 specimens, and while statistically significant differences were observed, larger studies may be needed to confirm these findings. Third, the study focused solely on the biomechanical aspects of hip stability and did not assess clinical outcomes such as pain relief and functional improvement following THA.

CONCLUSION

Future research should explore the long-term effects of prior arthroscopic interventions on THA outcomes in clinical settings. Additionally, studies incorporating computational modelling and finite element analysis may provide further insights into the biomechanical alterations associated with prior labral repair.

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Surgeons should consider these findings when planning THA in patients with a history of hip arthroscopy, as adjustments in implant positioning, soft tissue balancing, and rehabilitation protocols may be necessary to optimize outcomes.

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