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Original Article

Limb Shortening Increases Risk for Dislocation in Primary Total Hip Arthroplasty

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Abstract

Background: Despite a significant number of publications exploring hip shortening during Total Hip Arthroplasty (THA) and its effect on dislocation, the long term outcomes have been poorly characterized. Our purpose is to discuss the factors affecting hip stability and the outcomes of primary THA in a group of patients whose limbs were shortened.

Methods: We retrospectively reviewed all primary THAs from our institution's joint database between 1998 and 2004. Patients with a minimum of 48 months follow up were included in our analyses. Patient demographics, radiographic measurements, and Harris hip scores were compared with outcomes. We developed a method using landmarks on pre and postoperative radiographs to measure overall shortening and shortening through the femoral component specifically.

Results: Mean follow up time was 84 months. 16 hips (16.8%) had dislocations. Student t-test comparing dislocated to non-dislocated hips showed overall shortening and shortening through the femoral component were both significantly associated with dislocation (p=0.0093, p=0.0066 respectively). Bivariate analysis showed that risk of dislocation increases with extent of shortening through the femoral component (p=0.012).

Conclusion: Hips that were shortened at their femoral components were more likely to dislocate. Furthermore, the degree of shortening corresponded with the degree of dislocation risk. Hip shortening is an important risk factor for postoperative dislocation, a major complication following THA.

Introduction

Dislocation is one of the most common complications following total hip arthroplasty and it has been associated with increased morbidity and healthcare costs, as it frequently requires surgical revision and intensive rehabilitation [1]. The rates of dislocation after THA vary from less than 1% to greater than 15% [2] but a larger series by Fraser and Wroblewski have shown an incidence as low as 0.6% (92 of 14,672) [3]. Increased dislocation rates have been attributed to patient factors such as advanced age, female gender, and increased body habitus as well as surgical factors [2].

Instability as a consequence of reduced soft tissue tension in the hip joint after surgery has spurred the development of new surgical techniques and prostheses [2,4,5]. Using an anterolateral approach to THA has been shown to reduce post-operative soft tissue laxity and dislocation rates compared to using a posterolateral approach [3,6,7]. Pellicci, et al. found that repairing soft tissue after THA reduced their dislocation rates from 4% to 0% in a prospective study evaluating 790 cases [8] and a more recent study reported similar results [9]. Furthermore, while it has been shown that lengthening the limb may result in limp, sciatica, and back pain [3], there is evidence that it leads to increased tissue tension and reduced risk of dislocation [2].

It has been theorized that shortening the leg during THA will reduce soft tissue tension and increase the likelihood of postoperative dislocation [2]. In fact, several researchers have shown such a correlation, but few studies have investigated it on a larger scale. The purpose of this study is to determine the outcomes of a large cohort of patients whose hips were shortened during primary THA and examine their hip stability during an extended follow up period.

Materials and Methods

The Tufts Medical Center joint database was used to conduct a retrospective chart and radiographic review on patients who underwent primary THA from 1998-2004. All arthroplasties were performed by a single-surgeon using a single-implant (DePuy S-ROM®, Pinnacle Cup®,

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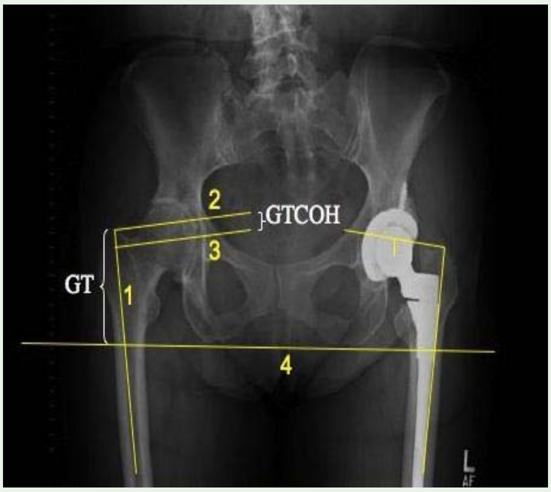

Figure 1: Hip Radiograph measurements. 1=Femoral shaft; 2=Line orthogonal to femoral shaft that intersects the tip of greater trochanter; 3= Line orthogonal to femoral shaft through center of femoral head; 4=Extended line connecting ischial tuberosities.

Marathon Liner®) through the posterolateral approach. All patients undergoing primary THA for Osteoarthritis (OA), Rheumatoid Arthritis (RA), or Avascular Necrosis (AVN) were included in this study. Due to the aim of this study specifically, patients were excluded if they did not have at least 48 months of follow up. 95 hips were selected for inclusion using these criteria. Data regarding patient demographics, components, preoperative and postoperative Harris Hip Scores (HHS), limb-length measurements, dislocation, and revision surgery were collected. Using the validated HHS system as a guide, pre- and post-operative HHS was determined via clinic note review.

Table 1: Baseline Demographic and Clinical Data.

Characteristic	
Age, mean (range), in years	61 (41-76)
Male / female ratio	42% / 58%
Hip side R (%) L (%)	 50 (53%) 45 (47%)
Follow-up, mean (minimum) in months	84 (48)
Indication for THA Osteoarthritis Osteonecrosis Rheumatoid Arthritis	 73 (77%) 13 (14%) 9 (9%)
Offset Standard Intermediate High	 15 47 33
Shell Size in males, mean (range), in mm	54 (48-60)
Shell Size in females, mean (range), in mm	50 (44-58)
Head Size 28mm 32mm 36mm	 57 (60%) 34 (36%) 4 (4%)
Head Offset, mean (range)	+3 (0 to +9)

We developed a methodology to assess hip length using pre and postoperative radiographs. Similar techniques have been used in previous literature to measure limb length to a precision of tenths of millimeters. [10] Measurements were made on either digital or hard copy radiographs. Bilateral measurements were made by drawing a line along the femoral shaft axis. Two lines orthogonal to the femoral axis were then drawn. The first line intersected the tip of the greater trochanter while the second line went through the center of the femoral head. Finally, an extended line was drawn connecting the distal tips of the ischial tuberosities. The distance between the two orthogonal lines was the Greater Trochanter to Center of Head Distance (GTCOH). The orthogonal distance from the greater trochanter to the ischial tuberosity line is the GTI (Figure 1).

Importantly, GTCOH compares two markers both on the femur and was used as a marker for lengthening/shortening in the femoral component, while GTI compares one marker on the femur to one marker on the pelvis, and was a surrogate for overall lengthening/ shortening.

Measurements of the contralateral hip were used to establish the patient's preoperative measurements if they were missing.

Statistical Analysis

Statistical analysis was performed using SAS version 9.2 (SAS Institute Inc, Cary, NC) with a two-tailed $p \leq .05$ for statistical significance. Data are presented as mean and standard deviations for continuous variables and percentages for categorical variables. Hip replacement characteristics, diagnoses, radiographic measurements, and hip dislocation rates were compared by sex; t-tests for normally distributed continuous variables and chi-square tests for categorical variables. Associations with dislocation were assessed by a multivariate logistic model adjusting for covariates of cupsize (mm), headsize (mm), pre-op to post-op difference GTI, pre-op to post-op difference GTCOH, and pre-op diagnosis (OA *vs.* Osteonecrosis *vs.* RA). Covariates were entered into a forward-stepwise regression if they met the 0.25 significance level and stayed in the model if they met the 0.10 significance level. We examined the relationship between pre-op to post-op difference GTI and pre-op to post-op difference GTCOH using Pearson Correlation analyses and removed GTCOH from the regression models. Finally, the time from date of surgery to date of dislocation for the 16 dislocation participants were compared by sex.

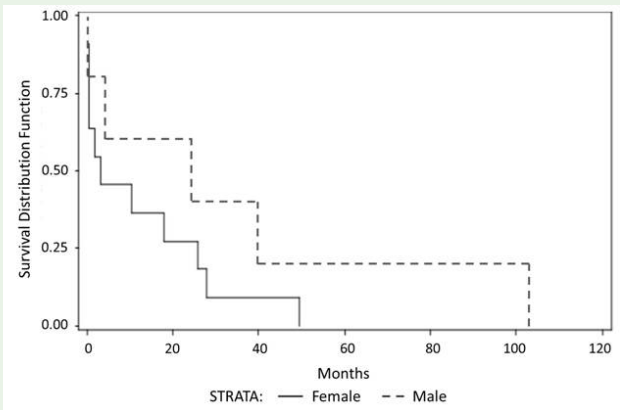

Figure 2: Kaplan Meier Survival Analysis.

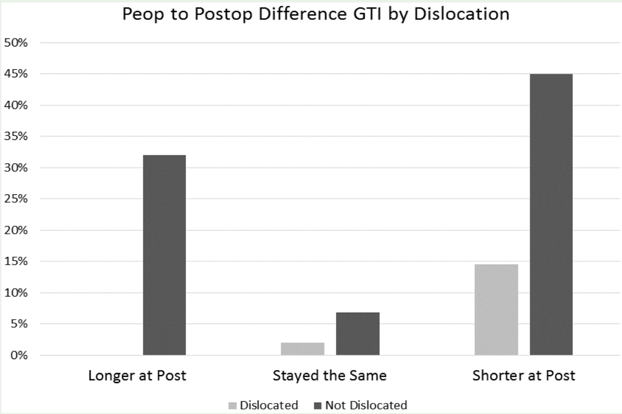

Figure 3: Dislocation as a function of LLD.

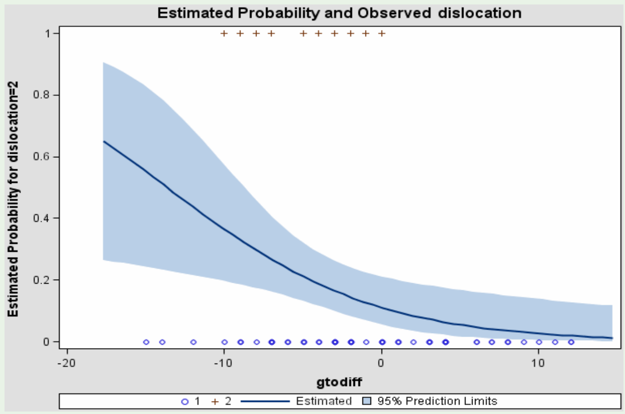

Figure 4: Dislocation as a continuous function of GTCOH diff.

Results

Forty of the hips examined were from male patients. There were 50 right hips and 45 left hips in the study. The minimum follow-up was 48 months, with a mean of 84 months. The underlying diagnosis leading to the primary THA was osteoarthritis in 73 hips, osteonecrosis in 13 hips, and rheumatoid arthritis in 9 hips.

Fifteen patients had a standard offset femoral component, 47 had an intermediate offset, and 33 had a high offset. The DePuy pinnacle cup, lined with standard cross-linked polyethylene, was used for all cases. The average shell size was 54mm (range 48-60mm) in males and 50mm (range 44-58mm) in females. The heads used were modular cobalt chrome. Most (57) hips in our series used the 28mm heads, 34 used the 32mm heads, and 4 hips used the 36mm heads. The mean head offset was +3, but ranged from 0 to +9. A summary of the demographic and clinical data can be found in table 1.

Data analysis revealed an overall mean shortening, GTI, of 0.7mm with a median shortening of 2.0mm. Overall mean shortening was greater in males (1.2mm) than females (0.3mm) but the median was identical in both populations (2.0mm). The overall mean shortening of shortened patients was 5.7mm. A majority of males and females were shortened after THA, 55% *vs.* 54.5%, respectively.

When looking at shortening through the femoral component, GTCOH, a similar pattern existed with identical proportions of males and females shortened (60% *vs.* 60%). The average shortening was 1.6mm, with shortening being more marked in males (2.1mm) than in females (1.3mm).

Our patient population showed marked improvement in HHS after THA with overall improvement in our study from a pre-op mean score of 48 to a post-op mean score of 91.

Table 2: Student t-test between dislocated and non-dislocated hips.

	Dislocation	No Dislocation	p-value
Cupsize (mm)	53.4 +/- 3.7	52.1 +/- 3.4	0.1778
Headsize (mm)	1.2 +/- 0.4	1.5 +/- 0.6	0.0633
Headlength (mm)	3.3 +/- 2.6	3.0 +/- 2.7	0.6296
PreOp HHS	48.1 +/- 14.3	47.4 +/- 14.7	0.9340
PostOp HHS	90.2 +/- 10.6	90.6 +/- 7.7	0.8777
GTI difference (mm)	-4.8 +/- 4.2	0.1 +/- 7.2	0.0093
GTCOH difference (mm)	-5.2 +/- 3.4	-0.9 +/- 5.9	0.0066

In this series there were 16 dislocations (16.8%), a majority of which occurred in females (11; 68.8%). This comprised 20% of all females undergoing primary THA as compared to 12.5% of males dislocating. Six of the primary THA operations required revision; 3 secondary to persistent joint instability, 2 for heterotopic ossification, and 1 for acetabular loosening. Of the 16 dislocated hips, 14 dislocated posteriorly and 2 anteriorly. Kaplan Meier Survival Analysis of dislocations by sex revealed a markedly shorter median time to dislocation among females (3.0 months) than males (24.4 months) (Figure 2).

T-test analysis showed that GTI (mean=-4.8mm, CI=0.6-9.0mm, p=0.0093) and GTCOH difference (mean=-5.2mm, CI=1.8-8.6mm, p=0.0066) are associated with an increased rate of dislocation. THA with smaller head size implant was associated with increased dislocation, but did not meet statistical significance (p=0.063). Cup size and head length were not associated with dislocation. These findings are summarized in table 2.

Chi-square analysis revealed that dislocated hips were more likely to be shortened as measured by GTCOH difference. Fourteen of the

Table 3: chi-squared analysis between dislocated and non-dislocated hips.

	Dislocation % (N)	Not Dislocated % (N)	p-value
Sex			
Male	11.58 (11)	36.84 (35)	0.3348
Female	5.26 (5)	46.32 (44)	
Neck Length			
0	5.88 (5)	31.76 (27)	0.9024
3	4.71 (4)	22.35 (19)	
6	7.06 (6)	28.34 (24)	
Headsize (mm)			
28	14.94 (13)	45.98 (40)	0.1725
32	3.45 (3)	33.33 (29)	
36	0 (0)	2.30 (2)	
Neck Offset			
Standard	3.45 (3)	13.79 (12)	0.2710
Intermediate	12.64 (11)	41.38 (36)	
High	2.30 (2)	26.44 (23)	
GTI difference			
Lengthened	2.11 (2)	35.79 (34)	0.0670
Same	2.11 (2)	5.26 (5)	
Shortened	12.63 (12)	42.11 (40)	
GTCOH difference			
Lengthened	0 (0)	31.58 (30)	0.0118
Same	2.11 (2)	6.32 (6)	
Shortened	14.74 (14)	45.26 (43)	

16 dislocations fell in the shortened group, with the remaining 2 being the same length post-operatively (p = 0.0118) (figure 3). No dislocations occurred in lengthened legs. Chi square analysis by GTI difference also demonstrated a similar pattern with 12 of the 16 dislocations occurring in patients that had been shortened, but was not statistically significant (p = 0.067). These findings are summarized in table 3.

Pearson correlation statistics show a large correlation between GTI and GTCOH difference (r=0.585, p<.05). This strong positive correlation indicates that, as expected, GTI and GTCOH both change reliably in the same direction. Our bivariate analysis showed that patients shortened through the femoral component had a significantly higher risk of dislocation as shortening increased (p = 0.012) (figure 4). Stepwise logistic regression further strengthens the relationship between GTI difference and dislocation (OR = 0.845; CI=0.751-0.950; p=0.0048).

Predicted probability plots from the logistic regression were created using one predictor variable at a time. The dislocation rate was found to increase with greater shortening of the femoral component (figure 4).

Discussion

Significant limb length discrepancy after THA is common, and, according to Williamson, et al. can occur in up to 27% of cases [11]. One of the most common complications after THA is dislocation, occurring at a rate of less than 1% to 15% [2]. Multiple studies have shown that femoral shortening is a risk factor for instability after THA [6,12, 13]. Woo, et al. found that limb shortening was directly related to increased incidence of dislocation [6]. Hip instability is multi-factorial, and is related to patient factors, choice of implant, component positioning and operative approach [14]. Despite the documented association between hip shortening and dislocation rates, some studies have not replicated these findings and instead showed that dislocated hips have not consistently been shorter than stable ones [6,12]. White et al showed no statistical association between limb-length discrepancy after THA in functional outcome or patient satisfaction [15]. Importantly, this study examines the long term effects of hip shortening. We believe that, depending on the magnitude of shortening, some patients may not initially have problems with instability, but their risk rises as they age and soft tissue laxity about the hip joint increases.

The Depuy S-ROM femoral component is a modular stem that allows the surgeon to adjust for height and offset through the femoral neck, independent of the offset of the femoral head. The use of alternative stems most likely would have allowed the surgeon to adjust for offset and height, however, the philosophy of the operative surgeon was to avoid lengthening of the lower extremity. The S-ROM system allows for maximal modularity and was thus the stem of choice in this series.

In our study, both overall and femoral shortening were associated with an increased dislocation rate. Chi-square and bivariate analysis demonstrated that femoral shortening was the most significant risk factor for dislocation. In fact, 14 of the 16 dislocations were shortened through the femoral component (p=0.012). The overall and femoral shortening were found to have a Pearson coefficient of 0.585, which suggests that the femoral component length is the greatest contributor to overall shortening. We also found that interval increases in femoral component shortening were predictive of increased rates of dislocation (figure 4), which has not been reported in the past. This strengthens the theory that suboptimal soft tissue tension may be the main mechanism behind dislocation.

Berry, et al. and other studies suggest a difference in dislocation rates when comparing small to large head sizes [16]. In our study, there was no statistically significant difference in dislocation rates when comparing head sizes.

Our high rate of dislocation may be explained by selection bias. Our inclusion/exclusion criteria required a minimum postoperative follow up period of 48 months, possibly excluding uncomplicated THAs with little reason to return for follow up and including a population of patients with a higher dislocation risk.

Our study is unique in that it investigated a large cohort of THA patients, a majority of which had post-operative shortening. The strength of our study lies in its large sample size, and long follow-up (mean 84 months). All THAs were performed by a single surgeon, using a single technique with similar implants, minimizing the impact of different surgical approaches and component types on dislocation rate. The limitations of this study include its retrospective nature and lack of a control group. Furthermore, radiographic limb length discrepancy was assessed without radiographic rulers.

In summary, hip instability is multifactorial and has been associated with limb length shortening in previous studies. Our study showed that shortening after THA was the most significant risk factor for instability in our population leading to dislocation in 20% of females and 12.5% of males. We concluded that the greater the magnitude of shortening in the femoral component, the greater the probability of dislocation. Since decreased soft tissue tension is associated with hip instability, optimization of soft-tissue tension at THA should be encouraged. In addition, intraoperative assessment of leg lengths should be emphasized, with particular attention paid to the femoral shaft length, as greater degrees of shortening increase the risk of dislocation.

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