Cup orientation in primary and revision total hip arthroplasty

Master thesis in Medicine
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1. Abstract

Background

Total hip arthroplasty (THA) is one of the most common surgical procedures today. Accurate orientation of the acetabular component is an important contributor to the survivorship of the prosthesis. Studies have considered different factors that may influence positioning of the cup but few have analyzed the difference between primary and revision procedures performed by a single surgeon.

Purpose

The purpose of this study was to determine whether there was a significant effect on overall cup orientation between primary and revision THA.

Patients and Methods

Three hundred sixty four consecutive THA procedures operated by a single surgeon at a tertiary hospital between 2011 and 2013 were identified. Among these, 172 primary and 133 revision THAs had proper radiographs. The version and inclination angles were determined by evaluating the Anterior Posterior Pelvic radiograph in Hip Analysis Suite ™. The cross-table lateral radiograph was then used to confirm anteversion or retroversion. Acetabular cups were considered acceptable if they were within the acceptable range zone 5-30° of anteversion and 30-50° of inclination, angles corresponding to conclusions made from prior studies. Furthermore were demographic data as age, Body Mass Index (BMI), gender, laterality of surgery, femoral head size, acetabular cup size and preoperative diagnosis considered if they have any association with cup positioning.

Results

63.4 % of the primary THAs and 68.4 % of the revision THAs were within acceptable range for both anteversion and inclination. No statistical significance was found in cup positioning between the two groups. In the revision group, “Moderately obese” (BMI>30 but <35) was associated with a significant risk of malpositioned cups, where they tended to exceed the acceptable degree of anteversion. Males had a lower risk of having their cups placed outside of the range than female in the revision group with an OR of 0.39 (*p*-value 0.016). In the primary group, age was found significant where >70 years of age were more likely to have their cups within acceptable ranges for anteversion with an OR of 0.40 (*p*-value 0.018) when compared to age 50-70 years old.

Conclusion

The acetabular component orientation was similar between primary and revision THA which indicate that an experienced surgeon is able to position the cup accurately in most cases even at revision surgery. However, in the revision group patients with BMI indicating “Moderately obese” and female gender were associated with malpositioned cups even when controlling for surgeon experience. Further, in the primary group lower age was associated with a higher risk of malpositioned cups. These results accentuate some of the many important factors that even the qualified surgeon must consider when performing either a primary or a revision THA.

Key words

Total hip arthroplasty, revision arthroplasty, acetabular cup positioning, anteversion, inclination.

2. Introduction

Total Hip Arthroplasty (THA) is a common and highly successful orthopaedic procedure and it is often called the “surgery of the century” (1). Many studies report good long-term clinical results in terms of survivorship of the prosthesis and improved quality of the patient’s life (1-3). However, the prevalence of revision THA is not insignificant. Also, the revision rate for any cause, has increased over the years regardless of improvements in surgical techniques and new developments in prosthesis design (4). Projections indicate that this trend will continue due to a population that tend to live longer and the fact that the procedures are being performed in younger and more active patients (5). With an older population the demands on the longevity of the prosthesis will increase.

The most common diagnosis for someone in need of a hip replacement is osteoarthritis (OA) and in Sweden, approximately 75 % of the procedures are performed because of OA (6). Hip fracture is another, upcoming, diagnosis for arthroplastic hip surgery today (6). Developmental dysplasia of the hip (DDH) is one of the most common reasons THA sometimes is needed in younger patients. A Norwegian registry study reports almost one third of all the THAs in patients younger than 60 years of age is due to DDH (7). Regarding a revised THA, the most common cause is dislocation followed by aseptic loosening and infection (8).

The survivorship of the prosthesis is a commonly discussed issue when it comes to THA (2-3) and the best would be if the prosthesis could last the patients’ remaining life. However, since the patients in need of a THA tend to both be younger and live longer (5) the importance of developing techniques and surgical factors helping to improve the prosthesis survivorship is topical. The orientation of the acetabular component is one well studied issue amongst several factors that contribute to the survivorship of the prosthesis. Malpositioned acetabular cups have been associated with several negative outcomes including a common cause for dislocation, increased wear, component loosening and migration, decreased range of motion and an increased risk of impingement (9-17). Several of these causes lead to the need of a revised THA. However, the factors that influence malpositioned cups are not fully understood and remain uncertain.

Assessment of the acetabular cup position includes anteversion and inclination. Anteversion is defined as the angle between the acetabular axis, as projected onto the transverse plan and the transverse axis. Inclination is the angle between the acetabular axis and the longitudinal axis of the patient (18). The initial description of "safe zone" parameters for acetabular cup version and inclination was published by Lewinnek et al. in an effort to identify risk factors for dislocation after THA (19). Subsequent studies have attempted to determine the optimal orientation, conflicting evidence for as low as 5° of anteversion and 25° of inclination and as high as 35° for anteversion and 55° of inclination have been suggested (17,19-22). Acetabular cups outside the ranges chosen in each study have been considered "malpositioned". Despite of the variability in accurate zones, the literature is consistent that the cup orientation is a critical factor for both long-term survivorship and short-term outcome (19).

To identify factors associated with increased malpositioning, several studies have retrospectively looked at patient data. As a result, several variables have been associated with cup orientation including Body Mass Index (BMI), age, femoral head size, surgical volume and surgical approach (21,23). Surgical factors that may adversely affect the cup positioning have also been assessed (24). However, the majority of studies have investigated factors associated with cup positioning in primary THAs and only a sparse number of studies regarding cup position in revision THAs (21, 25) or comparison of cup position between primary and revision THA (21, 26). Distorted anatomy of the acetabulum and more restrained exposure, as often occurs in revision cases, affect surgical planning and final result although it remains uncertain if this affects the position of the cup in the end. Furthermore, previous studies have compared primary and revision THA in cases from multiple surgeons. Surgical experience and procedure volume are two of the most reproducible and significant factors related to cup positioning (21-22, 27) where more experienced surgeons with higher procedure volume tend to place the cups more correctly compared with less experienced. This study includes cases performed by a single high-volume arthroplasty surgeon in order to better control for surgeon effects. This study sought to analyze positioning of cups within and between primary and revision THA to estimate whether or not there is a difference in version and inclination angles between the two groups. Furthermore the study aims to identify risk factors that might specifically affect revision cup accuracy. All included THAs are performed by the same, experienced surgeon since previous studies already have proven that surgeon experience in fact has an influence on cup positioning.

3. Aim of study

The main purpose was to evaluate if procedure type as primary or revision THA have a significant effect on overall cup positioning accuracy in a consecutive set of patients performed by a single, high-volume surgeon at a tertiary hospital. The null hypothesis of this study was that there are no differences between primary and revision THA in cup orientation. The secondary aim of the study was to evaluate if there are any patient or surgical variables associated with malpositioned acetabular cups within each group when looking at primary and revision THAs separately.

4. Patients and Methods

A consecutive series of 364 patients undergoing either a primary or a revision THA performed by the same surgeon between January 2011 and December 2013 were identified. A revision is stated as a THA having one or both of the components in the prosthesis replaced and in this study, it was defined as any case in which the acetabulum has previously undergone surgical manipulation resulting in distortion of the acetabulum. The cases where only the stem was revised were excluded. Post-operative Anterior/Posterior (AP) Pelvic radiograph and cross-table lateral radiograph were required for inclusion into the study. Demographic information was collected prospectively including age at the time of surgery, laterality of the operative hip, gender, initial diagnosis and BMI of the patient prior to surgery. Surgery specific factors including implanted femoral head size and acetabular cup size were also collected.

Several cases were excluded from the study. Of the 364 patients undergoing either a primary or a revision THA, 11 were excluded due to lack of proper post-operative radiographs. Of the patients who underwent a revision THA, 48 were excluded because these were cases where the cup was not revised (only stem revised). The final study population consisted of 305 cases, 172 primaries and 133 revisions.

The index diagnosis for surgery was divided into seven categories, avascular necrosis (AVN), developmental dysplastic hip (DDH), fracture, infection, inflammatory, osteoarthritis (OA) and post-traumatic arthritis (PTA).

BMI of the patient was categorized using The World Health Organization’s classification on BMI. Due to a small number, 4, of patients within the group of underweight (<18.5), these patients were included within the “healthy weight” category (18.5-25) to generate a combined category of “nonobese” with BMI <25. BMI >25 was categorized into “overweight” (>25 but <30), “Moderately obese” (>30 but <35) and “Severely obese” (>35). Data for BMI was missing for two primary and six revision cases and these patients were therefore excluded from the analysis of BMI. The age at surgery was divided into three groups for the statistics: less than 50 years, 50-70 years and above 70 years. Femoral head sizes were analyzed as either less than or equal to 32 mm, including one with 26 mm and two with 28 mm and the other group included head sized greater than 32 mm. (Table 1). The different types of prosthetic devices in both the primary and revision surgeries were all manufactured by Zimmer (Warsaw, IN, USA).

5. Measurement procedure

The cup position was measured using the Martell Hip Analysis Suite™ (HAS, Chicago, IL, USA), version 8.0.4.1(28). The AP Pelvic radiograph was measured in HAS to determine the cup version and inclination angles. The cross-table lateral radiograph was then checked to confirm anteversion or retroversion of the cup. The radiographs were measured in HAS by the same single validated reader and all cases were separately reviewed and confirmed by a second validated reader. In order to validate a reader, a training set was carried out using 20 postoperative and follow-up AP pelvic radiographs. These 20 radiographs were from different THAs and were not any of the primary or revision patients within this study. The reader performed the measurement for each pair three times and was obliged to reread each pair until all three rounds were correct and within one standard deviation from the previous round. The outcomes were also compared to an established set of results. Neither the primary nor the second reader were involved in anything around the surgery or care of the patients.

5.1 Statistics

Statistical analysis was performed using the computing environment R. Target ranges of acetabular components were based on "surgeon's goal" during surgery and prior literature corresponding to 5-30° of anteversion and 30-50° of inclination and were chosen as this study's "safe zone" (19,21-22). "Overall accuracy" was when taken both anteversion and inclination into account. Furthermore, were seven different surgical- and patient related variables analyzed for association with acetabular cup malpositioning, including age, BMI, gender, femoral head size, acetabular cup size, side of surgery and index diagnosis.

A power analysis was completed in Chi-Square test to examine how many patients were needed to find a trustworthy result. Total sample size necessary for a small to moderate effect (phi=0.2), power of 0.8 (ß=0.2), and α=0.05 was found to be 272 cases. Following sample collection, power analysis was repeated to determine the effect size that could reasonably be detected. This study included 305 cases and at the same power and significance, an effect size of 0.19 should be detectable. For subgroup analysis, there were 172 primary THAs and 133 revision THAs with the same power and significance thresholds this would be able to detect a moderate to large effect size in each sample, 0.25 and 0.29 respectively.

A Chi-Square Test or Fisher Exact Test was used for comparison of demographic variable between primary and revision THA. Accuracy of anteversion, inclination and overall cup accuracy (within ranges for both anteversion and inclination) were used as dependent variables in a generalized logistic model. Logistic models for each demographic variable were carried out independently to assess their effect on the respective accuracy category (anteversion, inclination and overall accuracy). The analysis was generated in both the primary and the revision group. For the combined set analysis, the independent demographic variable and whether it was a primary or revision were included in the model as well as their interaction term. Significant factors identified within each of the three groups: all patients, primary and revision group associated with acetabular cup malpositioning were included in a multivariate logistic model to identify individual odds ratio (OR) for each demographic or surgical factor. An OR <1 indicated a decreased risk for malpositioned cups and an OR >1 indicated an increased risk for malpositioning. All statistics were considered significant with a *p*-value <0.05.

6. Ethics

The study was conducted under Institutional Review Board (IRB) approval. The study is a retrospective observational study and no identifiable parameters were used in the study. No further information was collected than the data obtained from the patient journals. The collected demographic data was decoded and published in a combined form, the ability to identify the individual patient is therefore not possible. The risk for the patients was considered minimal.

7. Results

Of all cases included in the study, the mean anteversion was 24.3 ± 8.6° and mean inclination was 43.4 ± 6.0°. No retroverted cups were found. Of all cups, 65.6 % were placed within the "safe zone" for both anteversion and inclination (figure 1A).

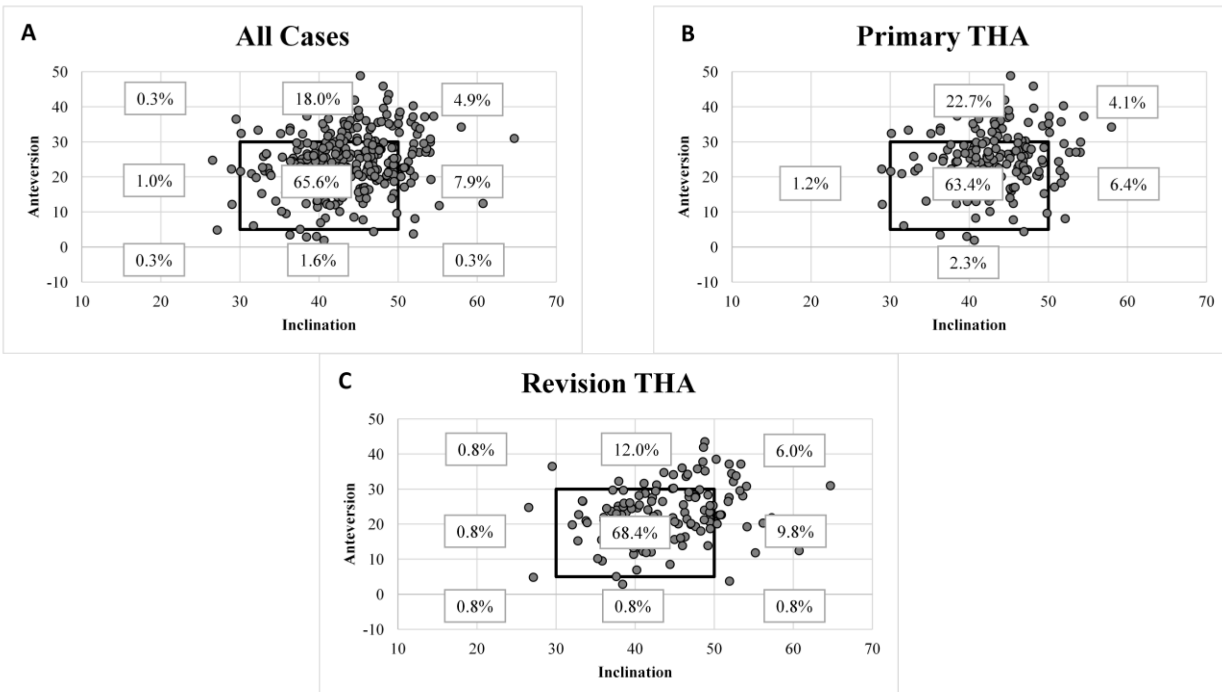

Figure 1: Scatter plots of anteversion and inclination. (A) Combined scatter plot for all cases in the study. (B) Scatter plot for Primary Total Hip Arthroplasty (THA) cases. (C) Scatter plot for Revision THA cases. The percentages describe cases within each area of the plots. Anteversion and inclination "safe zone" is shown by a bold box and corresponds to 5°-30° of anteversion and 30°-50° of inclination.

When looking at anteversion alone, 70.9 % of the primary and 78.9 % of the revision cases were in acceptable range, while in inclination, 88.4 % of the primary and 81.2% of the revision cases were in the acceptable range (Table 1). Cases within the safe zone for both anteversion and inclination were 63.4 % and 68.4 % for the primary and the revision cases respectively (figure

1B and 1C). There was no observed significant difference between primary and revision cases regarding anteversion and inclination respectively or “overall accuracy” (Table 1).

Table 1: Demographic Variables of Primary and Revision Total Hip Arthorplasty Cases. Shown are the average numbers and percentages of the different factors included in the analysis. Frequency *p*-values are shown for the overall comparison between primary and revision cases. Significant values are shown in bold (*p*-value <0.05).

Demographics		**Type of Arthroplasty**		
		Primary	**Revision**	
Factor	**Subgroups**	(n=172)	(n=133)	***p* -val**
Gender	Male / Female	78M / 94F	65M / 68F	0.54
Side	Left / Right	82L / 90R	63L /70R	0.96
Age	mean ± SD	63.7 ± 14.6	64.3 ± 12.5	0.70
	Age<50	26 (15.1%)	14 (10.5%)	0.12
	Age 50-70	81 (47.1%)	78 (58.6%)	
	Age>70	65 (37.8%)	41 (30.8%)	
Anteversion	mean ± SD ^{o}	25.1 ± 8.9	23.3 ± 8.1	0.066
	Out of Range	50 (29.1%)	28 (21.1%)	0.11
	Within Range (5-30)	122 (70.9%)	105 (78.9%)	
Inclination	mean ± SD ^{o}	43.1 ± 5.4	43.7 ± 6.7	0.35
	Out of Range	20 (11.6%)	25 (18.8%)	0.081
	Within Range (30-50)	152 (88.4%)	108 (81.2%)	
Accuracy	Within Both Ranges	63 (36.6%)	42 (31.6%)	0.36
	Out of Range	109 (63.4%)	91 (68.4%)	
Diagnosis	AVN	7 (4.1%)	8 (6.0%)	**0.00012**
	DDH	3 (1.7%)	17 (12.8%)	
	Fracture	9 (5.2%)	5 (3.8%)	
	Infection	5 (2.9%)	13 (9.8%)	
	Inflammatory	11 (6.4%)	6 (4.5%)	
	OA	116 (67.4%)	77 (57.9%)	
	PTA	21 (12.2%)	7 (5.3%)	
Head	≤32mm	143 (83.1%)	28 (21.1%)	**0.00000**
	>32mm	29 (16.9%)	105 (78.9%)	
Cup	48-50mm	42 (24.4%)	29 (21.8%)	**0.00000**
	52-54mm	89 (51.7%)	27 (20.3%)	
	56-58mm	35 (20.3%)	36 (27.1%)	
	60-62mm	5 (2.9%)	25 (18.8%)	
	>62mm	1 (0.6%)	16 (12.0%)	
BMI (kg/m^2)		(n=170)	(n=127)	
	mean ± SD	29.8 ± 5.6	29.3 ± 6.8	0.49
	Normal (BMI < 25)	29 (17.1%)	40 (31.5%)	**0.0041**
	Overweight (25 ≤ BMI < 30)	63 (37.1%)	38 (29.9%)	
	Moderately Obsese (30 ≤ BMI < 35)	52 (30.6%)	23 (18.1%)	
	Severely Obese (BMI ≥ 35)	26 (15.3%)	26 (20.5%)	

AVN- Avascular Necrosis, BMI- Body Mass Index, DDH-Developmental Dysplasia of the hip, OA- Osteoarthritis, PTA- Post-traumatic Arthritis, SD-Standard Deviation.

Between the primary and the revision group, the demographic data had some significant differences (Table 1). Overall BMI was not significant between the two groups with an average BMI of 29.8 for the primary group and 29.3 for the revision group. However, once BMI was divided into subgroups, primary THAs had significantly more patients within the BMI-group "Moderately obese". The index diagnosis for surgery was significantly different between the two groups. The most common diagnosis for both groups was OA. However, in the revision group there were more DDH and infections whereas in the primary group PTA (Post-traumatic Arthritis) and inflammatory were more common. Though the index diagnostic spectra differed between the two groups there was no significance in cup positioning when taking the diagnosis into account. In the primary group, 55 % of the patients were female and in the revision group, 51 % were female. The mean age at the date of surgery was 64 years for both groups. 85 % of the primary and all of the revision surgeries were performed with the use of a posterior approach on the operation table. The revision group had significantly more patients with larger head size and shell diameter compared to the primary group (Table 1).

Overall accuracy and anteversion accuracy alone were significantly improved in males in the group consisting of all patients and in the group consisting of only revisions (Table 2 and 3). No significant result was found for any of the variables in inclination accuracy alone (Table 4). Males were more likely to have cups within ranges and after the multivariate logistic analysis, OR in the revision group was found to be 0.39 (*p*-value 0.016) for overall accuracy and 0.34 (*p*-value 0.019) for anteversion accuracy when comparing to female (Table 5).

Table 2: Factor Effect on Overall Accuracy of Acetabular Cup Placement. Numbers and percentages for cases with anteversion between 5º-30º and inclination between 30º-50º of the acetabular component are shown for all cases as well as for primary and revision cases. *P*-values are shown within each of the three groups and significant *p*-values are shown in bold (*p*-value<0.05).

Overall Accuracy		**All Patients**			**Primaries**			**Revisions**		
Factor	**Subgroup**	**Within Range** (n=200)	**Outside of Range** (n=105)	***p*-val**	**Within Range** (n=109)	**Outside of Range** (n=63)	*p*-val	**Within Range** (n=91)	**Outside of Range** (n=42)	***p*-val**
Gender	Male / Female	105M / 95F	38M / 67F	**0.0067**	54M / 55F	24M / 39F	0.15	51M / 40F	14M / 28F	**0.015**
Side	Left / Right	98L / 102R	47L / 58R	0.48	53L / 56R	29L / 34R	0.74	45L / 46R	18L / 24R	0.48
Age				0.56			0.21			0.71
	Age<50	29 (14.5%)	11 (10.5%)		19 (17.4%)	7 (11.1%)		10 (11.0%)	4 (9.5%)	
	Age 50-70	101 (50.5%)	58 (55.2%)		46 (42.2%)	35 (55.6%)		55 (60.4%)	23 (54.8%)	
	Age>70	70 (35.0%)	36 (34.3%)		44 (40.4%)	21 (33.3%)		26 (28.6%)	15 (35.7%)	
Diagnosis				0.79			0.33			0.91
	AVN	12 (6.0%)	3 (2.9%)		6 (5.5%)	1 (1.6%)		6 (6.6%)	2 (4.8%)	
	DDH	14 (7.0%)	6 (5.7%)		3 (2.8%)	0 (0.0%)		11 (12.1%)	6 (14.3%)	
	Fracture	9 (4.5%)	5 (4.8%)		6 (5.5%)	3 (4.8%)		3 (3.3%)	2 (4.8%)	
	Infection	13 (6.5%)	5 (4.8%)		4 (3.7%)	1 (1.6%)		9 (9.9%)	4 (9.5%)	
	Inflammatory	10 (5.0%)	7 (6.7%)		7 (6.4%)	4 (6.3%)		3 (3.3%)	3 (7.1%)	
	OA	122 (61.0%)	71 (67.6%)		67 (61.5%)	49 (77.8%)		55 (60.4%)	22 (52.4%)	
	PTA	20 (10.0%)	8 (7.6%)		16 (14.7%)	5 (7.9%)		4 (4.4%)	3 (7.1%)	
Head				0.32			0.49			0.94
	≤32mm	108 (54.0%)	63 (60.0%)		89 (81.7%)	54 (85.7%)		19 (20.9%)	9 (21.4%)	
	>32mm	92 (46.0%)	42 (40.0%)		20 (18.3%)	9 (14.3%)		72 (79.1%)	33 (78.6%)	
Cup				0.18			0.15			0.75
	48-50mm	39 (19.5%)	32 (30.5%)		20 (18.3%)	22 (34.9%)		19 (20.9%)	10 (23.8%)	
	52-54mm	80 (40.0%)	36 (34.3%)		61 (56.0%)	28 (44.4%)		19 (20.9%)	8 (19.0%)	
	56-58mm	48 (24.0%)	23 (21.9%)		23 (21.1%)	12 (19.0%)		25 (27.5%)	11 (26.2%)	
	60-62mm	23 (11.5%)	7 (6.7%)		4 (3.7%)	1 (1.6%)		19 (20.9%)	6 (14.3%)	
	>62mm	10 (5.0%)	7 (6.7%)		1 (0.9%)	0 (0.0%)		9 (9.9%)	7 (16.7%)	
		(n=193)	(n=104)		(n=107)	(n=63)		(n=86)	(n=41)	
BMI				0.10			0.080			**0.023**
	Normal (BMI < 25)	66 (34.2%)	35 (33.7%)		35 (32.7%)	28 (44.4%)		31 (36.0%)	7 (17.0%)	
	Overweight (25 ≤ BMI < 30)	49 (25.4%)	26 (25.0%)		32 (29.9%)	20 (31.7%)		17 (19.8%)	6 (14.7%)	
	Moderately Obsese (30 ≤ BMI < 35)	38 (19.7%)	31 (29.8%)		18 (16.8%)	11 (17.5%)		20 (23.3%)	20 (48.8%)	
	Severely Obese (BMI ≥ 35)	40 (20.7%)	12 (11.5%)		22 (20.6%)	4 (6.3%)		18 (20.9%)	8 (19.5%)	

AVN- Avascular Necrosis, BMI- Body Mass Index, DDH-Developmental Dysplasia of the hip, OA-Osteoarthritis, PTA- Post-traumatic Arthritis.

Table 3: Factor Effect on Anteversion Accuracy of Acetabular Cup Placement. Numbers and percentages for cases with anteversion between 5°-30° of acetabular components are shown for all cases and for primary and revision cases separately. *P*-values are shown within each of the three groups and significant *p*-values are shown in bold (*p*-value <0.05).

Anteversion		**All Patients**			**Primaries**			**Revisions**		
Factor	**Subgroup**	**Within Range (5-30)** (n=227)	**Outside of Range** (n=78)	***p*-val**	**Within Range (5-30)** (n=122)	**Outside of Range** (n=50)	*p*-val	**Within Range (5-30)** (n=105)	**Outside of Range** (n=28)	***p*-val**
Gender	Male / Female	117M / 110F	26M / 52F	**0.0054**	60M / 62F	18M / 32F	0.11	57M / 48F	8M / 20F	**0.016**
Side	Left / Right	112L / 115R	33L / 45R	0.28	59L / 63R	23L / 27R	0.78	53L / 52R	10L / 18R	0.16
Age				0.24			**0.041**			0.71
	Age<50	32 (14.1%)	8 (10.3%)		20 (16.4%)	6 (12.0%)		12 (11.4%)	2 (7.1%)	
	Age 50-70	112 (49.3%)	47 (60.3%)		50 (41.0%)	31 (62.0%)		62 (59.0%)	16 (57.1%)	
	Age>70	83 (36.6%)	23 (29.5%)		52 (42.6%)	13 (26.0%)		31 (29.5%)	10 (35.7%)	
Diagnosis				0.29			0.071			0.93
	AVN	12 (5.3%)	3 (3.8%)		6 (4.9%)	1 (2.0%)		6 (5.7%)	2 (7.1%)	
	DDH	15 (6.6%)	5 (6.4%)		3 (2.5%)	0 (0.0%)		12 (11.4%)	5 (17.9%)	
	Fracture	13 (5.7%)	1 (1.3%)		9 (7.4%)	0 (0.0%)		4 (3.8%)	1 (3.6%)	
	Infection	16 (7.0%)	2 (2.6%)		5 (4.1%)	0 (0.0%)		11 (10.5%)	2 (7.1%)	
	Inflammatory	12 (5.3%)	5 (6.4%)		8 (6.6%)	3 (6.0%)		4 (3.8%)	2 (7.1%)	
	OA	136 (59.9%)	57 (73.1%)		74 (60.7%)	42 (84.0%)		62 (59.0%)	15 (53.6%)	
	PTA	23 (10.1%)	5 (6.4%)		17 (13.9%)	4 (8.0%)		6 (5.7%)	1 (3.6%)	
Head				*0.055*			0.28			0.56
	≤32mm	120 (52.9%)	51 (65.4%)		99 (81.1%)	44 (88.0%)		21 (20.0%)	7 (25.0%)	
	>32mm	107 (47.1%)	27 (34.6%)		23 (18.9%)	6 (12.0%)		84 (80.0%)	21 (75.0%)	
Cup				0.13			0.23			0.79
	48-50mm	45 (19.8%)	26 (33.3%)		24 (19.7%)	18 (36.0%)		21 (20.0%)	8 (28.6%)	
	52-54mm	87 (38.3%)	29 (37.2%)		66 (54.1%)	23 (46.0%)		21 (20.0%)	6 (21.4%)	
	56-58mm	57 (25.1%)	14 (17.9%)		27 (22.1%)	8 (16.0%)		30 (28.6%)	6 (21.4%)	
	60-62mm	25 (11.0%)	5 (6.4%)		4 (3.3%)	1 (2.0%)		21 (20.0%)	4 (14.3%)	
	>62mm	13 (5.7%)	4 (5.1%)		1 (0.8%)	0 (0.0%)		12 (11.4%)	4 (14.3%)	
		(n=220)	(n=77)		(n=120)	(n=50)		(n=100)	(n=27)	
BMI				0.10			0.19			**0.014**
	Normal (BMI < 25)	77 (35.0%)	24 (31.1%)		42 (35.0%)	21 (42.0%)		35 (35.0%)	3 (11.1%)	
	Overweight (25 ≤ BMI < 30)	54 (24.5%)	21 (27.3%)		35 (29.2%)	17 (34.0%)		19 (19.0%)	4 (14.8%)	
	Moderately Obsese (30 ≤ BMI < 35)	45 (20.5%)	24 (31.2%)		20 (16.7%)	9 (18.0%)		25 (25.0%)	15 (55.6%)	
	Severely Obese (BMI ≥ 35)	44 (20.0%)	8 (10.4%)		23 (19.1%)	3 (6.0%)		21 (21.0%)	5 (18.5%)	

AVN- Avascular Necrosis, BMI-Body Mass Index, DDH-Developmental Dysplasia of the hip, OA- Osteoarthritis, PTA- Post-traumatic Arthritis.

Table 4: Factor Effect on Inclination Accuracy of Acetabular Cup Placement. Numbers and percentages for cases with inclination between 30°-50° of acetabular components are shown for all cases and for primary and revision cases separately. *P*-values are shown within each of the three groups. No factors were found to be significant according to inclination accuracy (*p*-values <0.05).

Inclination		**All Patients**			**Primaries**			**Revisions**		
Factor	**Subgroup**	**Within Range (30-50)** (n=260)	**Outside of Range** (n=45)	***p*-val**	**Within Range (30-50)** (n=152)	**Outside of Range** (n=20)	*p*-val	**Within Range (30-50)** (n=108)	**Outside of Range** (n=25)	***p*-val**
Gender	Male / Female	126M / 134F	17M / 28F	0.18	71M / 81F	7M / 13F	0.32	55M / 53F	10M / 15F	0.32
Side	Left / Right	134L / 126R	19L / 26R	0.44	73L / 79R	9L / 11R	0.80	53L / 55R	10L / 15R	0.41
Age				0.56			0.39			0.75
	Age<50	36 (13.8%)	4 (8.9%)		25 (16.4%)	1 (5.0%)		11 (10.2%)	3 (12.0%)	
	Age 50-70	136 (52.3%)	23 (51.1%)		71 (46.7%)	10 (50.0%)		65 (60.2%)	13 (52.0%)	
	Age>70	88 (33.8%)	18 (40.0%)		56 (36.8%)	9 (45.0%)		32 (29.6%)	9 (36.0%)	
Diagnosis				0.27			0.43			0.38
	AVN	14 (5.4%)	1 (2.2%)		7 (4.6%)	0 (0.0%)		7 (6.5%)	1 (4.0%)	
	DDH	17 (6.5%)	3 (6.7%)		3 (2.0%)	0 (0.0%)		14 (13.0%)	3 (12.0%)	
	Fracture	9 (3.5%)	5 (11.1%)		6 (3.9%)	3 (15.0%)		3 (2.8%)	2 (8.0%)	
	Infection	14 (5.4%)	4 (8.9%)		4 (2.6%)	1 (5.0%)		10 (9.3%)	3 (12.0%)	
	Inflammatory	14 (5.4%)	3 (6.7%)		10 (6.6%)	1 (5.0%)		4 (3.7%)	2 (8.0%)	
	OA	169 (65.0%)	24 (53.3%)		103 (67.8%)	13 (65.0%)		66 (61.1%)	11 (44.0%)	
	PTA	23 (8.8%)	5 (11.1%)		19 (12.5%)	2 (10.0%)		4 (3.7%)	3 (12.0%)	
Head				0.17			0.81			0.49
	≤32mm	150 (57.7%)	21 (46.7%)		126 (82.9%)	17 (85.0%)		24 (22.2%)	4 (16.0%)	
	>32mm	110 (42.3%)	24 (53.3%)		26 (17.1%)	3 (15.0%)		84 (77.8%)	21 (84.0%)	
Cup				0.14			0.61			0.27
	48-50mm	60 (23.1%)	11 (24.4%)		35 (23.0%)	7 (35.0%)		25 (23.1%)	4 (16.0%)	
	52-54mm	102 (39.2%)	14 (31.1%)		81 (53.3%)	8 (40.0%)		21 (19.4%)	6 (24.0%)	
	56-58mm	60 (23.1%)	11 (24.4%)		30 (19.7%)	5 (25.0%)		30 (27.8%)	6 (24.0%)	
	60-62mm	27 (10.4%)	3 (6.7%)		5 (3.3%)	0 (0.0%)		22 (20.4%)	3 (12.0%)	
	>62mm	11 (4.2%)	6 (13.3%)		1 (0.7%)	0 (0.0%)		10 (9.3%)	6 (24.0%)	
		(n=253)	(n=44)		(n=150)	(n=20)		(n=103)	(n=24)	
BMI				0.69			0.35			0.46
	Normal (BMI < 25)	85 (33.6%)	16 (36.4%)		52 (34.7%)	11 (55.0%)		33 (32.1%)	5 (20.8%)	
	Overweight (25 ≤ BMI < 30)	67 (26.5%)	8 (18.2%)		47 (31.3%)	5 (25.0%)		20 (19.4%)	3 (12.5%)	
	Moderately Obsese (30 ≤ BMI < 35)	57 (22.5%)	12 (27.2%)		27 (18.0%)	2 (10.0%)		30 (29.1%)	10 (41.7%)	
	Severely Obese (BMI ≥ 35)	44 (17.4%)	8 (18.2%)		24 (16.0%)	2 (10.0%)		20 (19.4%)	6 (25.0%)	

AVN- Avascular Necrosis, BMI-Body Mass Index, DDH-Developmental Dysplasia of the hip, OA- Osteoarthritis, PTA- Post-traumatic Arthritis.

BMI was a significant factor on the overall accuracy in the revision group (Table 5). Revision THAs were significantly more prone to have cups outside of the ranges if they were moderately obese. BMI was included in the multivariate logistic model to quantify the increased risk, where moderately obese had an increase OR of 4.35 (*p*-value 0.0046) to have the acetabular cup outside the acceptable ranges for "overall accuracy" when comparing with a revision THA with normal BMI. Furthermore, moderately obese patients had an OR of 7.14 (*p*-value 0.0045) increased risk of having their cups malpositioned in anteversion alone. In the primary group, patients older than

70 years of age had improved cup accuracy compared to patients between 50 and 70 years old. A multivariate logistic model showed an OR of 0.40 (*p*-value 0.018) more likely to have accurate cup anteversion when comparing patients over 70 years old with patients between 50 and 70 years old (Table 3 and 5).

Table 5: Multivariate Logistic Model Results for Significant Factors. Factors found within each of the three groups, all patients, primary and revision group, to be significantly associated with acetabular cup positioning were included in a multivariate logistic model. The individual odds ratios (OR) for the model coefficients are shown with their 95% confidence intervals. An OR >1 indicates an increased risk for malpositioned cups whereas an OR <1 indicates a decreased risk for malpositoning. Significant *p*-values are shown in bold.

Patient Group	Factor	Comparison Group	Metric of Accuracy	Odds Ratio (95% CI)	*p* -val
All patients	**Gender:**				
	Male	Female	Combined Accuracy	0.51 (0.30-0.83)	**0.0070**
	Male	Female	Anteversion	0.48 (0.27-0.80)	**0.0060**
	Age:				
	<50 years	50-70 years	Anteversion	0.48 (0.16-1.28)	0.16
	>70 years			0.40 (0.18-0.84)	**0.018**
Revision	**BMI:**				
	Overweight (BMI 25-30)	Normal (BMI < 25)	Combined Accuracy	1.56(0.44-5.56)	0.48
	Moderately Obese (BMI 30-35)			4.35(1.64-12.5)	**0.0046**
	Severely Obese (BMI ≥ 35)			1.91 (0.61-6.67)	0.26
	Overweight (BMI 25-30)	Normal (BMI < 25)	Anteversion	2.44 (0.49-14.29)	0.27
	Moderately Obese (BMI 30-35)			7.14 (2.04-33.33)	**0.0045**
	Severely Obese (BMI ≥ 35)			2.78 (0.62-14.29)	0.19
	Gender:				
	Male	Female	Combined Accuracy	0.39 (0.18-0.83)	**0.016**
	Male	Female	Anteversion	0.34 (0.13-0.81)	**0.019**

BMI- Body mass Index, CI- Confidence Interval

8. Discussion

Malpositioning of the acetabular cup is an important factor associated with complications of the hip arthroplasty. Several reports consider different factors contributing to a better cup position in primary THA but only a few have studied the difference in cup positioning between primary and revision cases (21, 26). Therefore, this study has analyzed if there are any significant differences in the orientation of the cup between primary and revision THA. Furthermore, the study also analyzed optimally oriented acetabular components based on patient and surgical variables and then considered if those factors had any correlation to the cup position.

In the overall set of patients, average anteversion of 24.3°±8.6° and average inclination of 43.4°±6.0° showed similar results as previous reported studies (21, 23, 25, 29). Regarding cup accuracy, 74.4% and 85.2% of the cups were within acceptable range for anteversion and inclination respectively. While using anteversion and inclination combined, 65.6 % of all cups were within the acceptable range. These results are similar to previous studies (21, 23, 25, 29). However, both the primary and the revision THAs tend to exceed the degree of acceptable anteversion, as seen in figure 1A, 1B and 1C, although this was not statistical significant. However, the surgeon used a posterior approach in 85 % of the primary THAs and all of the revision THAs. THAs performed using a posterior approach have a higher incidence of dislocation (30) and the surgeon might have had this in mind and placed the acetabular cups a bit overanteverted to avoid posterior dislocation. Also, no retroverted cups were found, a described factor for posterior dislocation (19).

Though the average version and inclination of all 305 cases here are similar to previous studies, the aim of this study was to evaluate the differences between primary and revision total hip arthroplasty acetabular cup positioning and if there are any variables with significant influence on cup position within each group separately. There was no significant difference found between primary and revision group in either anteversion, inclination or overall accuracy. This study shows similar results as previous studies (21, 25, 26), where no statistical significant differences between primary and revision cases were found in cup orientation. However, when patient- and specific surgical factors were taken into account, several variables were significantly associated with malpositioned cups.

Regarding to revision cases, male gender had increased chance of having the cup placed within the acceptable range both in overall accuracy and especially anteversion (Table 5). This finding was also significant for the entire dataset, yet it was more pronounced in the revision group and not significant in the primary group. This result has, to the knowledge of the author of this thesis, not previously been reported. One possible explanation might be that the female pelvis is anatomically wider and have a higher rate of shallow or dysplastic acetabuli (31-32). Greater anatomical anteversion has also been reported in the native female pelvis (33). The latter might suggest that primary female THAs also should be more likely to have malpositioned acetabular cups. However, an important factor is that during a primary THA, the surgeon often has the advantage of matching the placement of the cup with respect to several anatomical references, whereas in revision cases such references are often absent due to the initial surgery. This study report that female gender tend to be more overanteverted in revision THA, however if the female acetabulum from the beginning tend to be anatomically more anteverted than the male pelvis the replaced cup needs to follow the anatomical diversity and the result will be a higher version than previously suggested (19, 21-22). Yet, there is no evidence that female revision THAs are more prone to dislocation or shorter survivorship of the prosthesis and further studies are needed to examine whether this is a risk for female patients. Perhaps the female and male population need separate angle goals. However, since this is not previously known, further studies need to be completed to examine the gender variation in cup accuracy closer.

BMI was another significant variable regarding overall accuracy and anteversion separately. This was true when comparing obese patients with normal weight patients in the revision group. Greater BMI increased the OR of malpositioned cups with 4.35 (p=0.0046) in moderately obese patients with BMI 30-35 compared to patients with a BMI below 25. There was an even more pronounced difference regarding anteversion separately with a 7.14 (p=0.0045) fold increased OR. BMI as a dependent variable in accurate cup position is reported in several previous studies (21-22). This supports earlier results and further suggests that BMI is an important factor, especially in revision cases. An explanation to the increased risk of malpositioning with increasing BMI might be that deeper incisions are needed due to more subcutaneous fat. The thickness of the subcutaneous fat also limits the exposure of the acetabulum for the surgeon. The increased BMI can complicate the positioning of the patient on the operation table which further causes difficulties during the surgery. Although, BMI is a measure of the weight and height and tells nothing about the co-morbidity, it would be of interest to divide the patients within each BMI group into subgroups of co-morbidity to examine if it is the body weight itself or if the increased BMI correspond with other diseases that might as well be associated with malpositioned cups. However, to do such research, more patients than involved in this study would be needed to get a sufficient data set to reach significance.

An interesting finding was that age had a significant association of cup anteversion within the primary THA but not in the revision group (Table 3). Patients older than 70 years were more likely to have cups accurately in anteversion than patients between 50-70 years, with an OR of 0.40 (*p*-value 0.018). This result is somewhat surprising since increased age often corresponds with a reduction in bone quality and higher incidence of osteoporosis. An explanation might be that it is easier to get exposure and prepare the acetabular bed in elderly patients with less muscles and lower bone quality. It is suggested that a bone of less quality is easier to manipulate as wanted. Another important factor to take into account is that younger patients undergoing THAs usually have another etiology of the arthrosis than the elderly where DDH (7) is a common cause. In DDH the anatomical structures are different from what is stated as "normal" whereas in OA, the most common cause for the elderly patients (6), the anatomical structures are often preserved.

Another finding between the two groups was that they were equal in average age (Table 1). It would have been expected that the revision group would have a higher average age, due to the reason that to get a revision, a primary THA must be performed at first. An explanation might be that the revision group had somewhat different index diagnosis, as seen in Table 1, where their primary THAs probably were needed to be performed earlier in their life. Also, it is more likely that a young and more active person will achieve a revision whereas in an elderly person there are more risks with surgery since they are more vulnerable to infections and risks associated with anesthesia.

No variables were significantly associated with malpositioned inclination angle either within the entire series nor when subgrouped into primary or revision THA. Previous studies have found that surgical experience is a positive predictor to accurate inclination (21-22). The surgeries in this study were performed by a single, high-volume arthroplasty surgeon with over 30 years of experience. The lack of significant findings regarding acetabular inclination might strengthen previous results of the importance of surgical experience.

The same ranges for acceptable anteversion and inclination for primary and revision THA are used and these ranges were established within primary THA cases. Though it stands to reason that many ideal biomechanical factors are similar for revision acetabular components as primary THA, no study has evaluated this *in vitro* or *in vivo*. Moreover, revision THA frequently involves compromised soft tissues, distorted bone requiring the surgeon to make intentional intraoperative changes to cup and stem position in order to improve implant stability. These changes may at times place components outside of the "acceptable" ranges identified in the literature for primary THA and the similar result of cup positioning for primary and revision THAs may somewhat be unexpected. The possibility to measure the cup position preoperatively in the revision cases with the use of preoperative radiographs and thereafter use this information for placement of the cup at surgery may be helpful. Any malpositioning of the cup during previous surgery would then be corrected at the revision and might explain the similar result of the revision and primary cases. Interestingly, this study does not only report similar mean anteversion and inclination angles between primary and revision THA cups, it also reports some of the same risk factors for inaccurate positioned cups as previous studies that were principally comprised of primary arthroplasty cases (19,22).

Acetabular component position in THA has been recognized as a significant factor affecting the longevity of implants. Many studies aimed at identifying ways of improving cup accuracy. The results in this study add BMI as an independent risk factor for malpositioned cups, specifically in revision cases, to the scientific field. Furthermore, there is a gender effect within revision THA, arguing that females have a greater risk of cup malpositioning, likely secondary to inherent differences in anatomic geometry. All these factors were significant even though this study only reported cases performed by a single, high-volume surgeon. Though this and other publications have reported similar factors contributing to the knowledge of component placement, it remains unclear as to whether being aware of these risk factors truly affects the prosthesis outcome. Thus, perhaps all surgeons should carefully consider variables as BMI, age and gender in order to improve the accuracy of the cup, independent of experience.

There are a couple of limitations to this study. The measurements done in HAS were calculated without taking notice of the rotational orientation of the femoral stem or accounting for the pelvic tilt which could bias the angles. During surgery, the cup could deliberately be placed in a position to match the femoral component and might explain why a cup is positioned outside the ranges, this is relevant especially in some cases of the revision THA where the stem from the previous surgery was retained. Studies have shown that the most accurate way of calculating the cup position is by using Computer Tomography (CT) (34-36), while this study used plain radiographs. Also, to take the femoral stem into account, a CT is necessary. The two groups, primary and revision THA were not fully equal in some aspects. The primary group had significant smaller head sizes than the revision group, whereas 83.1 % had a head diameter *below or equal to* 32 mm compared to the revision group where 78.9% had a head diameter *above* 32 mm (Table 1). This is also true for the shell sizes where primary cases had significantly smaller cup diameter than the revision cases. However, this is anatomically explained with the fact that a revision case needs a larger cup size than used in the previous surgery. In a revised THA, the hip and the acetabulum are already anatomically changed from the first surgery and the new shell must exceed the size of the first surgery. Even though a larger head size is inevitable, it is also an advantage since it increases the stability. It is also important to point out that the pelvis is in supine position on the radiographs used for the measurements and during the surgery the patient is lying on its side on the operation table. Version and inclination can be slightly different and tend to change in a standing position (37) and the functional acetabulum might differ from the measurements in the supine position.

Furthermore, it would have been of great interest to follow these patients and recognize the number of dislocations and loosening and correlate for cup positioning. However, this is only possible if the patients had been included in a prospective study or a nationwide registry study from the beginning. This would be an idea for a future study where the patients could be followed from the beginning. In Sweden, a nationwide “Hip replacement registry” exists (6). Interestingly would be to add acetabular cup positioning as a variable within this registry and follow the survivorship of the prosthesis.

This study used a single high-volume surgeon to control for surgeon’s effect, however it is important to remember that the results from this study could differ from THAs performed by a lower-volume surgeon. Although a very experienced surgeon performs a THA the out of range placement is not without importance and there is need for improved guiding tools and techniques. Since THA is one of the most common surgeries efforts must be done to improve the procedure.

9. Conclusion and implications

The null hypothesis stated for the study is verified since no statistical significant differences were found between primary and revision THAs overall. However, when divided into subgroups significances can be detected. Increased BMI is significantly associated with malpositioning of acetabular components even when controlling for surgeon experience and volume. Interestingly, female gender was found to be a significant risk factor for malpositioning in revision THA. This may be caused by gender differences in pelvic anatomy and the frequent necessity during revision THA to rely on more distant pelvic geometry, as local acetabular anatomy is frequently distorted. Finally, patients younger than 70 years were significantly more likely to have their cups inaccurately placed during primary THA. Together, these results help to underscore some of the important factors even the experienced surgeon must consider when performing both primary and revision THA. The most important conclusion to point out is the need of improved guiding tools and techniques to help even the experienced and high volume surgeons to place the acetabular cups in a correct position.

10.Populärvetenskaplig sammanfattning

Höftproteskirurgi brukar kallas för ”Århundradets kirurgi” då det har hjälpt många människor att få livskvaliteten tillbaka efter att ha levt med smärta till följd av sin ledsjukdom. Denna kirurgi har således varit revolutionerande, dock kvarstår många frågetecken kring protesens ”överlevnadsförmåga” i höften. Det är fortfarande relativt vanligt att man får göra en omoperation där man får byta ut sin gamla protes mot en ny på grund av komplikationer såsom infektion eller lossning av den gamla protesen. En höftprotes består av två delar; en stam med tillhörande kula vilken placeras ner i lårbenet, samt en ledskål vilken ersätter ledpannan och fästs i själva höftbenet som höftkulan ledar emot. Flertalet studier har påvisat att ledskålens placering i höftbenet kan påverka risken för komplikationer såsom lossning av protesen eller att höftkulan hoppar ur led. Inom ortopedin är det väletablerat att ledskålen bör vara placerad inom vissa gradantal för att minska risken för dessa komplikationer. Med hjälp av ett specifikt program kan man på en röntgenbild mäta vilka grader ledskålen är placerad inom och därefter dra olika slutsatser gällande faktorer som kan påverka att ledskålen hamnar fel.

Denna studie har undersökt om det finns någon skillnad i ledskålens placering mellan de som opereras första gången, så kallade ”primära höftproteser”, och de som oavsett orsak opererar om och byter ut sin ledskål från en redan befintlig protes, så kallade ”revisioner”. Studien har jämfört 172 stycken primära höfter med 133 stycken revisioner för att se om det finns någon skillnad i deras placering. Anledningen till studien var att de flesta tidigare studier endast har undersökt de primära höftproteserna. Vid en revision kan kroppens naturliga anatomi ha blivit något förändrad på grund av första operationen och det kan även vara svårare för ortopeden att se och komma åt ordentligt vilket kan göra det svårare att placera den nya ledskålen optimalt. En känd faktor gällande att ledskålen hamnar utanför de optimala gradantalen är att en mindre erfaren kirurg utför operationen. I denna studie ingår därför endast protesoperationer utförda av en rutinerad kirurg.

Resultatet visade att det inte finns någon skillnad i ledskålens placering mellan primära eller reviderade höftproteser, utan att de är placerade likmässigt. Däremot påträffades några intressanta fakta i grupperna var för sig. En kvinna som genomgår en revision har större risk att få sin ledskål utanför de optimala gradantalen än vad en man har. Vidare har en person som är mellan 50-70 år större risk att få sin ledskål utanför de optimala gradantalen vid en primär höftprotesoperation jämfört med en person som är över 70 år. Dessutom har en patient med högre BMI en större risk att få sin ledskål felplacerad. Dessa aspekter är viktiga för ortopeder att ha i åtanke vid framtida höftoperationer. Viktigt att poängtera är att det för dessa patienter inte är undersökt om de har en ökad andel komplikationer, utan det är bara noterat att de har ökat antal av felplacerade ledskålar. Ytterligare studier är motiverade för att undersöka om faktorer som kön, ålder och BMI har en ökad andel komplikationer.

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