Mako Total Hip arthroplasty:
clinical summary

Mako clinical evidence

Version 8

1. Introduction

Total hip arthroplasty (THA) has been one of the most successful procedures within the field of orthopaedics since the late 1960s.[1] Despite its high success, mechanical failure, aseptic loosening, and component malpositioning leading to dislocations are some of the most common reasons for revision THA.[2] These complications can be mitigated using intraoperative techniques such as an adequate preoperative planning that can help surgeons better understand a patient's specific anatomy, thus identifying the most optimal component positioning.[2] The Mako System was introduced with a goal of providing more accurate to plan implant positioning while leveraging the benefits of computed tomography (CT) imaging to help restore anatomy, reduce the risk of postoperative complications, enhance patient outcomes, provide an efficient user experience, and lower costs. This document summarizes the evidence to date that supports the use of the Mako System for total hip arthroplasty.

Figure 1. Pre-operative planning screen with 3D reconstruction of pelvis and femur depicting leg length and combined offset.

2. What is Mako THA?

Mako Total Hip Application (Mako THA) is a robotic assisted software application that utilizes segmented, CT scans to generate a 3D model reconstruction of the pelvis and proximal femora to aid in the creation of a patient-specific preoperative plan (Figure 1).[3] Mako THA is designed to minimize the margin of error associated with restoring native hip biomechanics while incorporating patient anatomy with a functional approach.

2.1 Accuracy with restoring native biomechanics

In a multicenter clinical trial including 110 patients, acetabular cup positioning was compared between preoperative plan, assessment, and achieved radiographic measure.[4] Results confirmed that intraoperative robotic assistance achieved greater accuracy in preparation and position of the acetabular cup during THA (Table 1).[5]

Gou et al. (2022) conducted a study aimed at evaluating whether higher accuracy of cup positioning can be achieved by robotic assisted THA.[6] This study showed that the planned inclination and anteversion of the acetabular cup were correlated with the actual postoperative measurements.[6] The difference between planned and actual measurement was 1.43±0.15° and 1.47±0.11°, respectively.[6]

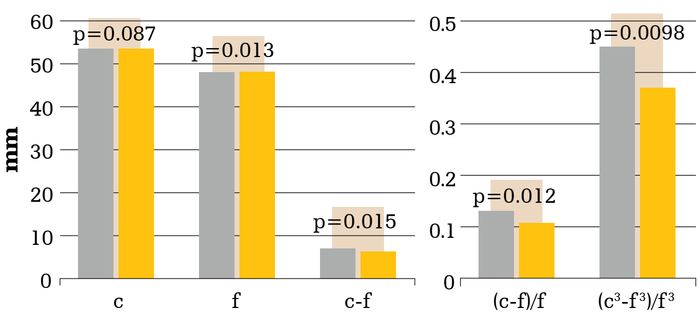
	Preoperative plan	Intraoperative robotic-arm measurements	Martell radiographic measurement
Inclination	40.0°±1.2°	39.9°±2.0°	40.0°±4.1°
Version	18.7°±3.1°	18.6°±3.9°	21.5°±6.1°
Count (n)	119	119	110

Table 1. The average inclination and anteversion values of the acetabular components in the study, showing the preoperative plan, measures recorded intraoperatively and those measured from plan radiographs using the Martell method.[5]

When utilizing a direct anterior (DA) approach in THA, most surgeons use fluoroscopic guidance to confirm the acetabular component position.[7] Literature has proposed that robotic assisted THA using DA approach may offer improved implant placement.[7] A clinical study compared the accuracy of acetabular component position between DA and posterior approach (PA) using robotic assisted THA, in the absence of fluoroscopic guidance.[7] The DA cohort conferred significantly higher accuracy with respect to inclination ($p=0.001$) and cup anteversion conferred better precision than PA.[7] This study also concluded that the acetabular component position using robotic assisted THA is both accurate and precise in most cases, regardless of surgical approach.[7]

Clinical evidence continues to build on the potential benefits of robotic assisted THA. Investigations have demonstrated that robotic assisted surgery significantly reduces leg length discrepancy compared to manual THA

Results: Bone stock



Conventional THA
Robotic-arm assisted THA

c-f = bone thickness lost over course of surgery

(c-f)/f = bone thickness lost through surgery per width of the femoral head

$(c^3-f^3)/f^3$ = volume of bone lost through surgery

Figure 2. Illustrates the Mako System's single reaming technique preserves bone as compared to conventional THA's sequential reaming technique.[10]

($p=0.001$) and is accurate to 1.0 ± 0.7mm for recreating leg length/offset.[6,8] Another publication highlighted the influence of head center of rotation (COR) on the risk of hip dislocation.[9] A potential benefit of robotic assisted THA is that it has been shown to be significantly more accurate and precise in reproducing head COR when compared to manual THA, which may result in reduced incidence of hip dislocation.[8]

Clinical studies have also shown that robotic assisted THA has been associated with more precise reaming, which can not only influence recreation of COR, but also impact preservation of bone stock.[10] Suarez-Ahedo et al. (2017) studied bone preservation during primary THA in a matched pair control study of conventional THA ($n=57$) and robotic assisted THA ($n=57$).[10] When comparing these matched cohorts, the robotic assisted THA allowed for more precise reaming and lead to the use of smaller acetabular cups in relation to the patient's femoral head size.[10] Using acetabular cup size relative to femoral head size as surrogate measure of acetabular bone resection, these results suggest that greater preservation of bone stock using robotic assisted THA compared to conventional THA. This may reflect increased translational precision during the reaming process (Figure 2).[10]

2.2 Incorporating patient anatomy with functional approach

Surgeons have been using the Lewinnek safe zone as a guide for cup placement for over 40 years.[11] However, studies have shown that greater than 50% of total hip arthroplasty dislocations have cups placed within the safe zone.[12,13] One shortcoming of the Lewinnek safe zone is that it generally applies to all patients, regardless of their individual bone morphology, kinematics, implant choices or placement.

Mako THA has incorporated features that allows a surgeon to assess a patient's change in pelvic tilt (PT) in the supine, standing and seated position as well as the ability to visualize range of motion to impingement using a virtual range-of-motion (vROM) tool. (Figure 3). O'Conner et al. found that PT can significantly change the functional orientation of the acetabular component and may differ markedly between patients (Figure 4).[14] They then used the vROM tool from Mako THA to assess the risk of impingement and investigate changes to implant position to reduce that risk.[14]

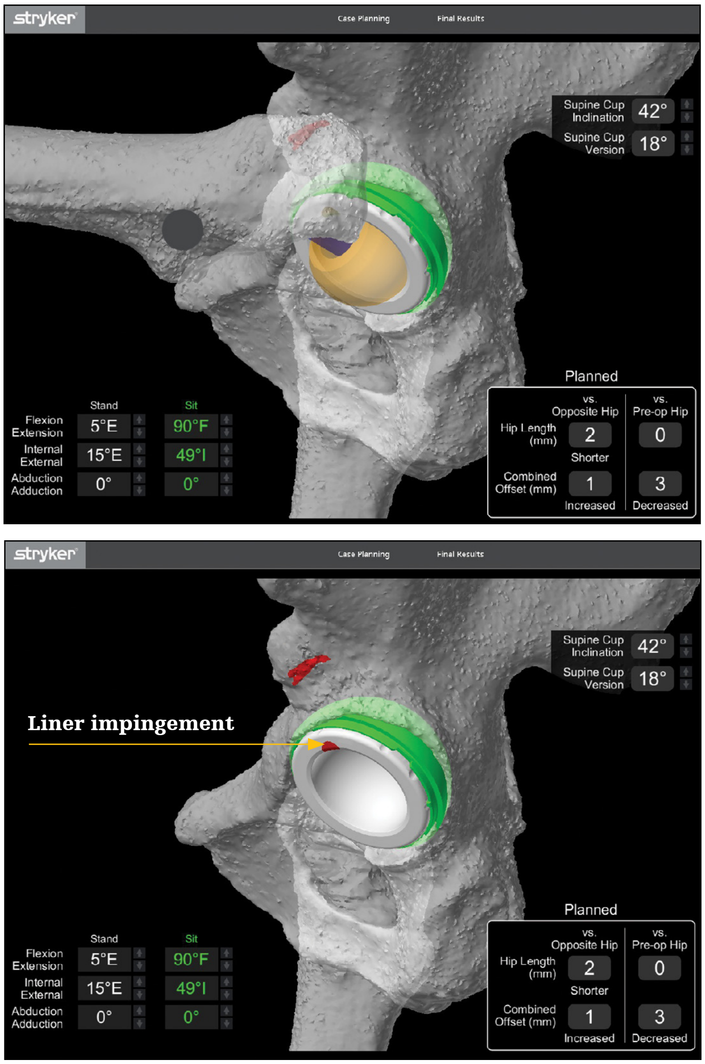


Figure 3. Mako THA has virtual range-of-motion tool indicating risk of impingement (highlighted in red). The surgeon is able to change implant position and/or implant systems to address impingement.

A prospective, multi-center clinical study was performed on a cohort of patients who received robotic assisted THA with integration of software to incorporate patient's PT and vROM.[15] The purpose of this study was to quantify the percentage of cases where the surgical plan deviates from a 40° inclination and 20° anteversion target based on spinopelvic mobility when considering functional implant planning.[15] Cases were separated into groups based on their preoperative spinopelvic mobility moving from standing to sitting.[15] 79.2% of cases were considered normal (change ≥ 10°) and 20.8% of cases were considered stiff (change < 10°).[15] For both groups, majority of cases (normal: 89.5%, stiff: 90.0%) deviated from the 40° inclination and 20° anteversion target and the average cup placed had greater inclination and anteversion then target.[15] Based on these findings, features of Mako THA, such as PT and vROM, can help surgeons visualize change in PT and vROM intraoperatively and make more informed decisions on implant planning based on a patient's native anatomy.

Deviation from a traditional 40°/20° plan was further evaluated in this multi-center study to understand how surgical approach may influence functional implant placement when performing robotic assisted THA.[16] The study showed significant difference in implant placement between the two surgical approaches.[16] DA approach is associated with greater concern for posterior impingement and therefore anterior dislocation, and PA is associated with greater concern for anterior impingement and therefore posterior dislocation.[16] Functional implant plans in this study reflected these considerations as the PA was associated with statistically significant more inclination and anteversion when compared to DA plans.[16] These results convey that surgical approach may influence a surgeon's functional implant placement and the vROM feature in the Mako THA can provide visual impingement information that may influence the surgical plan.

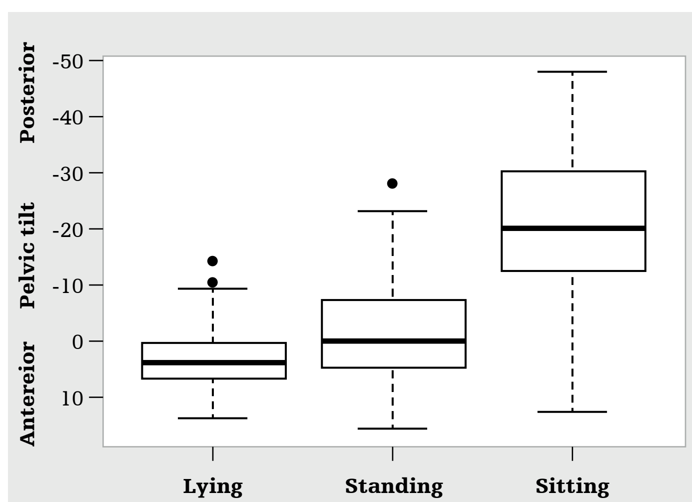


Figure 4: O'Conner et al. found high variability in preoperative lying, standing, and sitting pelvic tilt (PT) in patients undergoing total hip arthroplasty.[14]

3. What are the clinical benefits of Mako THA?

Clinical benefits resulting from a patient-specific plan afforded by Mako THA have been shown to reduce the rate of dislocation, enhance postoperative patient outcomes, and improve patient recovery and satisfaction. Results of studies in this area are promising.

3.1 Reduction of dislocations

Dislocations following primary THA is a well-known complication, and instability is a leading cause of revision THA in many national joint registries.[17] The treatment of recurrent instability is revision THA, which is associated with high cost of hospitalization, prolonged length of stay, and continuing increased risk of further instability compared with primary THA.[17] Clinicians and researchers have emphasized the importance of patient-specific preoperative planning and intraoperative strategies to achieve targets that may reduce the risk of dislocation.[17]

In a retrospective, single-surgeon review of 300 THAs, the rate of dislocation at one year follow up was studied in three groups of patients: 1) the surgeon's first 100 manual THA cases (2000-2001); 2) the surgeon's last 100 manual THA cases (2010-2011) and 3) the surgeon's first 100 Mako Total Hips cases (2011-2012).[18] Dislocation rates between the three groups were significantly different and dislocation was more frequent in group one (5/100, 5%) and group two (3/100, 3%) than group three (0/100, 0%) at one year follow up.[18]

Bendich et al. (2022) conducted a retrospective study at a single institution of 13,802 THAs (1,700 robotic assisted THA, 3,155 computer navigated THA, and 8,877 manual THA) between 2016 – 2020.[19] The odds ratio of re-operation for dislocation were 0.3 for robotic assisted THA compared to manual THA ($p=0.046$).[19] The odds ratio of re-operation for dislocation were 3.0 for computer navigated THA compared to robotic assisted THA, though this did not reach statistical significance ($p=0.114$).[19] At one year follow up, there was a statistically significant decreased risk of reoperation due to dislocation with robotic assisted THA and a lower rate of dislocation requiring reoperation compared to manual THA.[19]

Additionally, a cohort study from Michigan Arthroplasty Registry Collaborative Quality Initiative. (MARCQI) of 2,247 consecutive patients (1,724 manual THA and 523 robotic assisted THA) compared dislocation rates and related revisions between manual and robotic assisted THA.[20] When compared to the manual group, the Mako THA cases reported lower periprosthetic dislocation rate without mechanical failure (0.57% vs. 2.49%, $p=0.007$).[20] All robotic assisted THA dislocations were successful with conservative treatment without recurrence, whereas 46% of traditional dislocations were ultimately revised for recurrent instability.[20]

These retrospective studies add to the evidence that the CT-based Mako THA shows reduced rates of dislocation compared to manual THA. The use of preoperative CT imaging allows surgeons to optimize implant placement and use Mako THA to accurately execute the preoperative plan.

3.2 Enhanced clinical outcomes

In the research conducted by Bukowski et al., outcomes for three groups of 100 consecutive THAs (first 100 manual THAs; last 100 manual THAs; and first 100 Mako Total Hips), were reviewed.[21] Mako THA resulted in significantly higher modified HHSs (92.1±10.5 vs. 86.1±16.2, p = 0.002) and UCLA activity levels (6.3±1.8 vs. 5.8±1.7, p = 0.033) than manual THA at minimum one-year follow-up (Figure 5 and Figure 6, Table 2).[21]

Marchand et al. have reported on early outcomes out to 1-year complications for a single surgeon's first 100 patients who underwent a Mako THA procedure with functional implant planning.[22] Between preoperative to 6 weeks postoperative, the RA-THA cohort achieved a statistically significant improvement (p<0.05) in their HOOS Jr score where this delta was also considered to be a substantial clinical benefit.[22] At three- six-months, and one-year follow-up, patients continued to have statistically significant improvement in HOOS Jr which represented a minimal clinically important difference.[22]

Perets et al. have compared minimum two-year outcomes and complications for patients who underwent a Mako THA procedure to patients where he performed manual THA.[23] Eighty-five Mako THA patients were pair-matched to manual controls based on patient

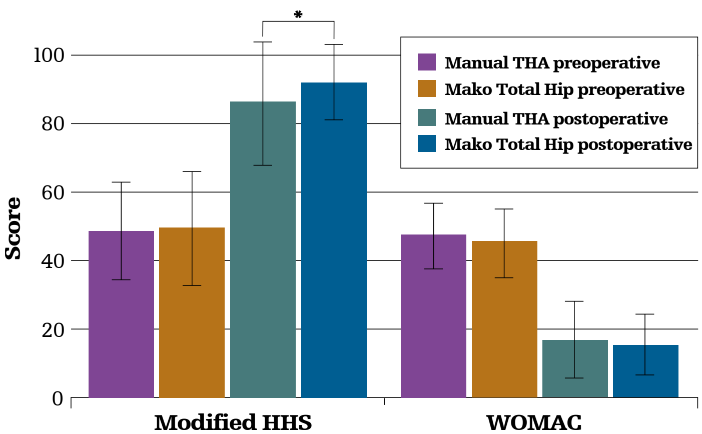


Figure 5: Statistically higher modified HHS were shown for Mako THA patients.[21]

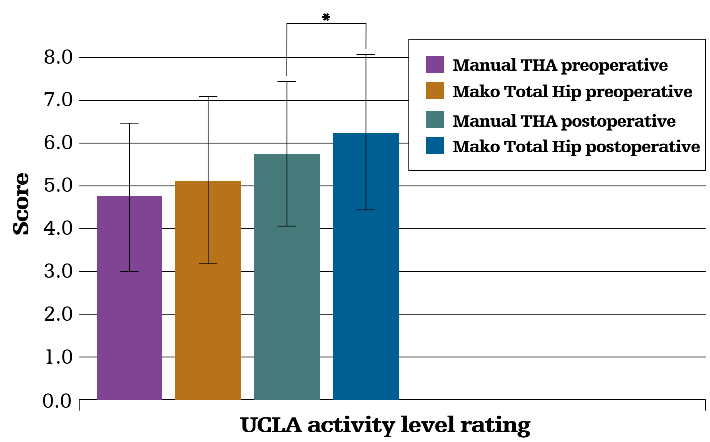


Figure 6: Statistically higher modified UCLA were shown for Mako THA patients.[21]

Patient-reported outcomes (PROMs) comparing rTHA and mTHA patient groups[11]

	Group (RATHA n=100, MTHA n=100)	Preoperative	Postoperative	PROMs (postoperative-preoperative)	p-value
mHHS (mean and standard deviation)	RATHA	49.6 (16.3)	92.1 (10.5)	43.0 (18.8)	<0.001
	MTHA	49.2 (14.8)	86.1 (16.2)	37.4 (18.3)	<0.001
	p-value	0.865	0.002	0.035	
SF12-MCS (mean and standard deviation)	RATHA	54.1 (10.4)	54.6 (9.1)	0.4 (9.7)	0.629
	MTHA	53.1 (9.6)	53.0 (10.2)	0.5 (11.5)	0.970
	p-value	0.459	0.245	0.962	
SF12-PCS (mean and standard deviation)	RATHA	33.5 (9.6)	46.0 10.5)	12.5 (11.8)	<0.001
	MTHA	30.3 (8.0)	44.4 (11.0)	14.0 (11.9)	<0.001
	p-value	0.010	0.282	0.404	
WOMAC (mean and standard deviation)	RATHA	45.6 (18.9)	16.0 (14.9)	-29.6 (21.4)	<0.001
	MTHA	47.1 (14.7)	17.3 (15.5)	-28.5 (18.3)	<0.001
	p-value	0.536	0.538	0.618	
UCLA (mean and standard deviation)	RATHA	5.1 (1.9)	6.3 (1.8)	1.2 (1.7)	<0.001
	MTHA	4.8 (1.8)	5.8 (1.7)	1.0 (1.9)	<0.001
	p-value	0.227	0.033	0.429	

Categorical analysis of modified Harris Hip Score

	rTHA	mTHA	
90-100	75.0% (75)	61.0% (61)	0.034
80-89	13.0% (13)	15.0% (15)	0.684
70-79	6.0% (6)	5.0% (5)	0.756
<70	6.0% (6)	19.0% (19)	0.005

Table 2: Summary of patient-reported outcomes comparing robotic assisted THA to manual THA.[21]

demographics. The patients prospectively reported on Harris hip score (HHS), Forgotten Joint Score-12 (FJS-12), Visual analog scale for pain (VAS), and satisfaction (scale ranging 0-10).[23]

The FJS-12 questionnaire has evidence of low-ceiling effects and is suitable for assessing longer term outcomes in well-performing groups after THA.[24] The literature has reported an FJS-12 ranging from 50.9 ± 25.3 to 80 ± 24 for patients who received manual THA.[23,24] Perets et al. reported an FJS-12 for the Mako THA patients of 80.2, which was significantly greater ($p=0.003$) than an FJS-12 of 68.6 reported by the manual THA control group.[23] The Mako group had a significantly higher HSS ($p<0.001$) and a trend towards having lower VAS scores ($p=0.120$) when compared to the control group. Additionally, at two years, the Mako group had less LLD (1.0mm, $p=0.013$), less global offset (0.9mm, $p=0.31$) and no dislocations reported in either group.[23] Postoperatively, one robotic assisted patient required a revision at 8.7 months after primary THA due to femoral stem loosening and three manual THA patients required revision at a mean 25.1 months postoperatively, all for femoral stem loosening.[23]

This same group of patients continued to be followed, and Maldonado et al. published on minimum five-year outcomes of this patient cohort.[25] When compared to a manual THA control group, the Mako THA cases reported significantly higher Harris hip scores ($p<0.001$), FJS-12 ($p=0.002$), Veterans RAND-12 physical component scores ($p=0.002$), and Short Form Health Questionnaire (SF)-12 physical component scores ($p=0.001$) (Table 3).[25] In addition, Mako THA recipients had lesser absolute values of leg length discrepancy and global offset ($p = 0.091$, $p = 0.001$). This study used multiple validated functional hip outcome scores to determine that patients who received Mako THA reported favorable outcomes at a minimum five-year follow-up.[25]

A similar trend was observed in a prospective study of 40 patients undergoing Mako THA that were propensity matched to 80 patients undergoing manual THA.[26] Groups were matched based on age, sex, and preoperative function. At 12-month follow-up, the Mako THA group had improved Oxford Hip Score (OHS, $p=0.038$), FJS ($p<0.001$), and less dissatisfied patients (Mako 0 vs. Manual 6).[26] The FJS in the Mako group was 21.2 points higher than the manual group which represented a minimal clinically important difference.[26] Based on radiographic analysis, the manual THA group had a decrease in the horizontal center of rotation, which was also associated with a decrease in acetabular offset.[26] This shift of center of rotation was not found in the Mako group. The authors hypothesized that this difference in restoration of hip center and leg length could have impacted the differences in clinical outcomes between the two groups.[26]

3.3 Early patient recovery and satisfaction

When exploring a patient's road to recovery, their length of stay in hospital after surgery is a key factor to consider. Shaw et al. retrospectively compared the length of stay of 523 Mako THA patients against those who received conventional THA ($n=1724$).[20] They reported the Mako THA patients were found to have significantly lesser average postoperative length of hospital stay ($p<0.001$) then conventional THA.[20] Additionally, 29.64% of Mako THA patients had a length of stay less than one day compared to 3.65% of conventional THA patients.[20]

Rosinsky et al. performed an analysis focused specifically on comparing patients who underwent robotic assisted THA either at an inpatient or outpatient facility.[27] The first 100 consecutive patients who underwent outpatient THA were matched to 100 patient who underwent inpatient THA during the same time period. After exclusions ended up with 91 patients. They compared perioperative variables including surgical time, blood loss, and length of stay as well as 90-day complication rates and 2-year patient reported outcomes. The outpatient group had an average length of stay of 6.8 hours compared to 43.2 hours for the inpatient group ($P < 0.001$). There were no significant differences between the groups regarding readmissions, emergency room visits, and unplanned clinic visits. Complications and revision rates were similar in both groups. However, in appropriately selected, younger patients, outpatient robotic assisted THA can achieve improved postoperative 2-year PROs compared to inpatient manual THA.[27]

Overall, data from these studies suggest that patients who undergo Mako THA may be able, on average, to return home sooner after surgery than those who undergo conventional THA. This may pose a great advantage

Patient-reported outcomes	Robotic-assisted THA	Manual THA	p-value
HHS	90.57±13.46	84.62±14.45	<0.001
FJS-12	82.69±21.53	70.61±26.74	0.002
VAS	1.27±2.20	1.07±1.87	0.45
Satisfaction	8.91±2.00	8.52±2.62	0.35
VR-12 mental	60.76±5.94	58.97±6.03	0.17
VR-12 physical	50.30±8.83	45.92±9.44	0.002
SF-12 mental	56.59±5.60	56.20±6.62	0.81
SF-12 physical	48.97±9.21	44.01±10.26	0.001

Table 3. Minimum five-year patient-reported outcomes for Mako THA and manual THA cohort.[25]

for patients' well-being and offer financial benefits to healthcare institutions, since a reduction in length of stay post-Mako THA surgery potentially reduces the economic burden of hospitals.[28]

In addition, patient satisfaction post-THA is high, as demonstrated by Perets et al., where patient satisfaction at a minimum of two-year follow-up was assessed.[23] For the 162 Mako THA cases considered in this study, mean patient satisfaction was a high 9.3 out of 10.[23]

3.4 Utilization of Mako THA in complex cases

Mako THA has been shown to be a useful tool for complex cases. Chai et al. carried out a case study that included three complex cases with hip dysplasia, ankylosing spondylolysis and post-traumatic arthritis, respectively.[29] In all three cases, the Mako System was utilized to help accurately implement the surgical plan.[29] Since there was an absence of conventional bony landmarks, the preoperative CT scan in these cases was instrumental in planning.[29] The hip dysplasia patient reported at three months postoperatively that they were able to walk without assistance, had no hip pain and were satisfied with their leg lengths.[29] The patient with ankylosing spondylolysis reported no hip pain and was able to walk with a walking frame at three months postoperatively.[29] The patient with post-traumatic arthritis reported no hip pain and was able to walk without assistance at three months postoperatively.[29] According to this study, the planning and accuracy of execution in Mako THA allowed the surgeon to give the patients excellent reconstruction of their hip joints which substantially enhanced their quality of life. The authors went on to say that Mako THA surgery may be considered for complex THA cases in order to achieve the desired accuracy of the reconstruction, especially in the absence of conventional bony landmarks.[29]

Kuroda et al. analyzed a consecutive series of 69 patients who underwent robotic assisted THA, where 30 of those patients had development dysplasia of the hip (DDH) and were classified according to the Crowe type.[30] Using the patients' preoperative plan and comparing to postoperative CT data, accuracy of cup alignment and 3D placement were compared between DDH and non-DDH patients.[30] No significant differences were found in cup placement between the two groups and excellent restoration of leg length and combined offset were achieved in both groups.[30] This study concluded that robotic assisted THA may achieve accuracy and reproducibility of cup placement in both non-DDH and DDH patients, even those with severe DDH.[30]

4. What are the user benefits of Mako THA?

Mako THA also has the potential to provide surgeons' an enhanced intraoperative experience such as reducing workload and improving efficiencies, regardless of experience level.

4.1 Reduce mental and physical demand during surgery

The Mako system provides a stereotactic boundary that guides the alignment of the robotic during acetabular reaming and cup insertion, helping the surgeon to ensure proper alignment. Additionally, the system provides a single ream option, potentially eliminating the need for the surgeon to perform multiple reams to achieve final ream size. It has been reported that 66.1% of arthroplasty surgeons have had a workplace-related injury, with 31% requiring surgery.[31] Assistance in performing reaming and cup insertion may enhance the ergonomic health and reduce the workload demand on the surgeon.[31]

A cadaveric study was performed to determine how the use of Mako THA can influence a surgeon's energy expenditure as well as mental and physical demand compared to manual THA.[32] Twelve THAs were performed by two surgeons, with varying robotic experience. Each cadaveric specimen received a manual THA on one hip and Mako THA on the contralateral side. During the procedures, each surgeon wore biometric shirts that allowed the measurement of biometric parameters including caloric expenditure and heart rate.[32] Following each surgery, surgeons were asked to perform a modified surgery task load index questionnaire to compare the physical and mental demands for the overall procedure, as well as various individual tasks.[32]

Mako THA demonstrated reduced surgeon energy expenditure compared with manual techniques (83.5kcal vs. 100kcal).[32] Aside from exposure of the joint space and retractor placement, surgeons reported lower physical demand during Mako THA for all other individual tasks and overall mental demand was lower when compared to manual THA.[32] Mental fatigue was significantly reduced during acetabular reaming with Mako THA versus manual THA ($p<0.05$).[32] One potential reason for these results is that during robotic assisted THA, surgeons use reamers that are held with a haptic boundary that enables surgeons to ream according to their preoperative plan.[32]

4.2 Efficient user experience

Kong et al. published a retrospective comparative cohort study of an experienced manual surgeon's first 100 robotic assisted THAs compared to the surgeon's last 100 manual cases.[33] The average operating time of robotic assisted THA was 95.92 ± 15.64 minutes, ranging from 68 to 145 minutes.[33] The learning curve was assessed using a cumulative summation test for learning curve analysis which demonstrated that after the 14th case, a downtrend in the surgeon's operative time began.[33] There was no statistical difference between the first 14 cases versus cases 15 to 100 when considering cup positioning, postoperative LLD, offset and Harris hip score (HHS).[33] Results indicate that there was a 14-case learning curve when considering operative time; however, the authors observed this learning curve did not impact patient outcomes.[33]

Another clinical study looked at a surgeon's learning curve, with over 10 years of experience in hip arthroplasty, based on the duration of the procedure.[6] The study collected operative time for both manual and robotic assisted THA and the operative time was significantly higher in the robotic assisted THA group then the manual THA (91.37 ± 17.34 minutes vs. 77.52 ± 6.17 minutes).[6] However, after 13 cases, the operating time in the robotic assisted THA group decreased significantly and gradually became stable.[6] Even with the existence of a learning curve of 13 cases, there was no statistical difference between the placement of the acetabular cup for patients in the robotic assisted THA and manual THA.[6]

4.3 Surgical outcomes across levels of surgeon experience

In a publication by Smith et al., they investigated if the accuracy of robotic assisted surgery was translatable to newer surgeons in their fellowship.[34] In a cadaveric study, two adult reconstruction fellows halfway through their training year performed manual THA (n=6) and robotic assisted THA (n=6).[34] The robotically prepared hips demonstrated statistically significant greater accuracy and precision to plan compared to the manually prepared hip when considering shell version, shell inclination and LLD.[34] Error in shell placement was reduced by up to 9mm and error in LLD was reduced by up to 8mm when using robotic assisted THA.[34] The authors concluded that these findings suggest that CT-based preoperative planning and intraoperative robotic technology, such as the Mako THA , can allow less experienced surgeons to place implant components more consistently in the desired orientation, with comparable accuracy to what has been reported by experienced surgeons.[34]

In addition to providing accuracy to plan for less experienced surgeons, Shapira et al. studied the use of the Mako THA as a learning tool for fellows training in hip arthroplasty.[35] The study evaluated the accuracy of fellows' estimation of cup and broach positioning using the Mako system. They found that the mean difference between estimated and actual cup inclination and version was 7.24° (P = 0.060) and 4.81° (P = 0.031), respectively.[35] Shapria et al. concluded that the robotic system is a useful learning tool for fellows in training to help them understand their own inaccuracies in estimating implant position and hence may help refine their abilities.[35]

5. Is Mako THA cost effective?

In assessing the potential effects of Mako THA on costs to US based private payers and Medicare, Maldonado and colleagues evaluated the long-term cost effectiveness of robotic vs. manual THA through a Markov model.[36] The potential outcomes of THA were categorized into the transition states: infection, dislocation, no major complications, or revision. Cumulative costs and utilities were assessed using a cycle length of one year over a time horizon of five years. They found that robotic assisted THA cohort was cost effective relative to manual THA cohort for cumulative Medicare and cumulative private payer insurance costs over the 5-year period.[36] Robotic assisted THA cost saving had an average differential of $945 for Medicare and $1,810 for private insurance relative to manual THA while generating slightly more utility (0.04 quality-adjusted life year).[36] The preferred treatment was sensitive to the utilities generated by successful robotic assisted THA and manual THA. Microsimulations indicated that robotic assisted THA was cost effective in 99.4% of cases.[36] In the US Medicare and private payer scenarios, robotic assisted THA is more cost effective than conventional manual THA when considering direct medical costs from a US payer's perspective.[36]

A separate US based Medicare analysis of the 90-day episode of care (EOC), 938 robotic assisted THA propensity matched to 4,670 manual THAs, found that robotic assisted THA patients were less likely to have post-index inpatient rehabilitation (IPR) or skilled nursing facility (SNF) admissions (0.64% vs. 2.68%; p<0.0001 and 20.79% vs. 24.99%; p=0.0041, respectively).[37] Robotic assisted THA patients used fewer days in post-index inpatient and SNF care (7.15 vs. 7.91; p=0.8029 and 17.98 vs. 19.64; p=0.5080, respectively) and used fewer home health aide (HHA) visits, (14.06 vs. 15.00; p=0.0006) compared to manual THA.[37] Robotic assisted THA had lower 90-day EOC costs for: IPR ($11,490 vs. $14,674; p=0.0470), SNF ($9,184 vs. $10,408, p=0.0598) and HHA ($3,352 vs. $3,496; p=0.0133) compared to manual THA.[37] Overall, robotic assisted THA patients had 12% ($948) lower average post-index costs compared to manual THA patients (p=0.0004).[23] Total 90-day episode-of-care costs for robotic assisted THA patients were found to be $785 less than those of manual THA patients ($19,734 vs. $20,519, p=0.0095).[37]

6. Conclusion

Mako THA offers the potential for surgeons to utilize a patient-specific plan to achieve more accurate to plan implant placement and enhance clinical outcomes. Studies have demonstrated that Mako THA led to decreased dislocations, decreased length of stay, improved outcomes, improved radiographic accuracy, decreased mental and physical demand, efficient user experience, and decreased costs.[2] Ultimately, the benefits of Mako THA may be experienced by all key players – patients, surgeons, and health systems.

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