

Robotic-Assisted vs. Conventional Arthroplasty: A Comparative Analysis of Postoperative Outcomes in Colombia

Artroplastia asistida por robot *versus* convencional: un análisis comparativo de los resultados posoperatorios en Colombia

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ABSTRACT

Introduction: Robotic-assisted knee and hip arthroplasty improves precision and outcomes but poses challenges such as longer operative times compared to conventional surgery.

Objectives: To compare clinical outcomes between conventional and robotic-assisted total knee and hip arthroplasty.

Methods: A retrospective cohort study was conducted on patients who underwent robotic-assisted or conventional arthroplasty between December 2023 and July 2024 at a high-complexity institution. Clinical and sociodemographic data were analyzed using statistical methods, including Kaplan-Meier survival analysis.

Results: 292 hip and knee arthroplasties, of which 59.6% were conventional and 40.4% with robotic assistance. Patients in the robotic group were older (median 72 vs. 68.5 years, $p = 0.021$) and more likely to reside in urban areas (97.5% vs. 87.4%, $p = 0.002$). Patients who underwent robotic surgery had a shorter median hospital stay compared to those who had conventional surgery (1 vs. 2 days, $p < 0.001$), lower postoperative Visual Analog Scale (median 0 vs. 1, $p = 0.045$), and fewer transfusions (1.69% vs. 8.67%, $p = 0.013$). The robotic group had a lower risk of prolonged hospitalization ($p < 0.001$).

Discussion: Robot-assisted hip and knee arthroplasty demonstrated significant benefits, including shorter hospital stays, lower VAS, and reduced transfusion. These outcomes suggest a potential for faster recovery and improved early postoperative results, particularly in older adults.

Conclusions: Robot-assisted arthroplasty emerges as a clinically advantageous approach. Despite longer operative times, its relation with improved postoperative outcomes and reduced resource demands supports its growing role in orthopedic practice.

Keywords: arthroplasty; replacement; knee; arthroplasty; replacement; hip; robotic surgical procedures; orthopedic procedures.

RESUMEN

Introducción: La artroplastia de rodilla y cadera asistida por robot mejora la precisión y los resultados clínicos, pero presenta desafíos como un mayor tiempo quirúrgico, en comparación con la cirugía convencional.

Objetivos: Comparar los resultados clínicos entre la artroplastia total de rodilla y cadera convencional y la asistida por robot.

Métodos: Se realizó un estudio de cohorte retrospectivo en pacientes sometidos a artroplastia (convencional o asistida por robot) entre diciembre de 2023 y julio de 2024 en una institución de alta complejidad. Se analizaron datos clínicos y sociodemográficos mediante métodos estadísticos, incluyendo análisis de supervivencia de Kaplan-Meier.

Resultados: Se realizaron 292 artroplastias de cadera y rodilla, de las cuales el 59,6 % fueron convencionales y el 40,4% asistidas por robot. Los pacientes del grupo robótico eran de mayor edad (mediana de 72 *vs.* 68,5 años, $p = 0,021$) y con mayor frecuencia residían en zonas urbanas (97,5 % *vs.* 87,4 %, $p = 0,002$). Los pacientes sometidos a cirugía robótica tuvieron una estancia hospitalaria más corta (mediana de 1 *vs.* 2 días, $p < 0,001$), menor puntuación en la escala visual análoga postoperatoria (mediana de 0 *vs.* 1, $p = 0,045$) y menos transfusiones (1,69 % *vs.* 8,67 %, $p = 0,013$). El grupo robótico presentó menor riesgo de hospitalización prolongada ($p < 0,001$).

Discusión: La artroplastia de cadera y rodilla asistida por robot mostró beneficios significativos, incluyendo estancias hospitalarias más cortas, menor dolor posoperatorio y menor necesidad de transfusiones. Estos resultados sugieren una recuperación más rápida y mejores resultados posoperatorios tempranos, especialmente en adultos mayores.

Conclusiones: La artroplastia asistida por robot se perfila como una opción clínicamente ventajosa. A pesar de los mayores tiempos quirúrgicos, su asociación con mejores resultados postoperatorios y menor uso de recursos respalda su creciente incorporación en la práctica ortopédica.

Palabras clave: artroplastia de reemplazo de rodilla; artroplastia de reemplazo de cadera; procedimientos quirúrgicos robóticos; procedimientos ortopédicos.

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Introduction

Knee and hip arthroplasty have long been the gold standard in the management of degenerative joint diseases and severe traumatic injuries, enabling patients to regain mobility and improve their quality of life.⁽¹⁾ These procedures have consistently demonstrated high rates of safety, effectiveness, and patient satisfaction.⁽²⁾ In recent years, however, orthopedic surgery has experienced significant technological innovation with the emergence of robotic-assisted systems.⁽³⁾ This advancement offers greater precision, enabling surgeons to meticulously plan each step of the surgery to anticipate and address potential complications, ultimately leading to better long-term outcomes and faster recovery times.⁽⁴⁾ Additionally, the global use of robotic technology in orthopedic procedures has increased steadily, with projections indicating that the market for robotic joint replacement surgeries will surpass USD 2.5 billion by 2030, driven by the growing demand for precision surgery in an aging population.⁽⁵⁾

Robotic-assisted knee and hip arthroplasty are advanced surgical techniques that employ robotic platforms to optimize implant positioning and improve surgical accuracy.⁽⁶⁾ This enhanced precision involves several critical aspects, including optimal implant alignment, accurate bone resections, improved component positioning, and restoration of mechanical axis, all of which contribute to better functional outcomes, reduced complication rates, and improved implant survival.⁽⁷⁾ These systems allow for meticulous preoperative planning through three-dimensional imaging of the affected joint, followed by intraoperative robotic assistance that executes precise bone cuts and implant placement according to the predetermined surgical plan, with real-time feedback and the capacity for intraoperative adjustments.⁽⁸⁾

The benefits of robotic-assisted arthroplasty have been widely reported in the literature. These include improved precision in implant alignment, reduced variability in surgical outcomes, decreased intraoperative blood loss, shorter hospital stays, faster functional recovery, and potential increases in implant longevity.⁽⁹⁾ Despite these advantages, robotic-assisted surgery also presents limitations, such as elevated costs, limited accessibility in developing healthcare

systems, longer operative times during the learning curve, and dependence on complex technology, which introduces the potential for technical malfunctions.⁽¹⁰⁾ In particular, the financial burden of acquiring, maintaining, and operating robotic platforms remains a significant barrier to widespread adoption, especially in resource-limited settings.^(11,12)

Currently, the most frequently utilized robotic systems in joint arthroplasty include Mako® (Stryker),⁽¹³⁾ predominantly for total knee and hip replacements; ROSA® (Zimmer Biomet),⁽¹⁴⁾ specifically for total knee arthroplasty; and NAVIO®,⁽¹⁵⁾ applicable for both partial and total knee replacements. Although the international evidence has demonstrated the advantages of robotic-assisted surgery, most of these studies have been conducted in high-income countries, with scarce data available for Latin American populations. Moreover, there is limited evidence evaluating the clinical outcomes of robotic arthroplasty specifically in patients over 80 years of age in Colombia, a demographic expected to increase significantly in the coming years. Despite the increasing adoption of robotic technology, this age group remains underrepresented in most clinical studies, and findings from other contexts may not be fully generalizable due to differences in population health profiles and healthcare system capabilities. Therefore, the objective of our study is to compare the clinical outcomes of patients undergoing conventional orthopedic surgery with those treated using robotic-assisted orthopedic surgery in a Colombian cohort. Specifically, we aim to answer the following research question: Are there significant differences in postoperative clinical outcomes between patients aged 80 and over undergoing robotic-assisted knee arthroplasty compared to conventional procedures in a high-complexity Latin American center?

Methods

An analytical retrospective cohort study was conducted between December 2023 and July 2024, involving patients who were consecutive cases undergoing surgery by orthopedics and who underwent total hip and knee arthroplasty, either with the Mako® robotic arm (Stryker) or conventional surgery, at a high-complexity institution in Colombia. Adult patients with degenerative joint damage requiring joint replacement after unsuccessful conservative treatments were included, provided they consented to participate and adhered to perioperative guidelines. Exclusion criteria included patients with acute knee injuries, medical conditions contraindicating anesthesia, neuromuscular disorders impairing muscle strength, active osteoarticular infections, and individuals in palliative care who would not benefit from joint replacement or lacked adequate social support. Additionally, patients requiring joint replacement due to primary or metastatic cancer, or those with soft tissue conditions limiting their functional capacity, were excluded.

A thorough review of medical records was conducted using the institution's electronic medical record system to extract relevant information. The following variables were considered: age, sex, admission diagnosis, area of residence, hospital stay, in-hospital mortality, type of anesthesia, procedure type, body mass index, days of preoperative planning, preoperative and postoperative transfusions, preoperative and postoperative hemoglobin levels, regional block, postoperative analgesics, postoperative opioids, postoperative non-steroidal anti-inflammatory drugs (NSAIDs), antibiotic prophylaxis, antithrombotic prophylaxis, preoperative Visual Analogue Scale (VAS), postoperative VAS, and readmission.

Statistical Analysis

The normality of continuous variables was assessed using the Shapiro-Wilk test, and for non-normally distributed variables, the Mann-Whitney U test was applied. Measures of central tendency and dispersion were used accordingly. Categorical variables were analyzed using absolute frequencies and percentages, with Chi-

square or Fisher's exact tests employed where appropriate. A Kaplan-Meier analysis was conducted to evaluate the length of hospital stay, with discharge as the outcome, comparing between the groups (conventional vs. robotic surgery). The statistical analysis also included the Log-Rank test to assess significant differences in hospital stay between robotic and conventional surgery. A multivariable logistic regression model was conducted to identify the factors independently associated with undergoing robotic-assisted surgery. The dependent variable was the type of surgery (robotic vs. conventional). Covariates included length of hospital stay, place of residence (urban or rural), and other clinically relevant variables selected based on prior literature and bivariate analysis. Odds ratios (OR) with 95% confidence intervals (CI) were estimated, and statistical significance was set at $p < 0.05$. Model performance was assessed using the area under the ROC curve (AUC).

Ethical statement

This study adheres to international ethical guidelines, ensuring that participants received standard clinical care unaffected by the research process. As a retrospective, non-interventional study, it introduced no additional risks to patients. Ethical approval was granted by the Technical Scientific Committee and the Research Ethics Committee (Approval No. 2024-016-13), confirming compliance with key ethical principles throughout the study.

Results

A total of 292 hip and knee arthroplasties were performed between 2023 and 2024, of which 59.59% were conventional surgeries and 40.41% were robotic-assisted surgeries. The median age of the patients was 68.5 years in the conventional group and 72 years in the robotic group, with a statistically significant difference ($p =$

0.021). Most of the patients were female in both groups (60.34% *vs.* 66.1%, $p = 0.318$), and the majority resided in urban areas (87.36 *vs.* 97.46%, $p = 0.002$).

The comparison between robotic and conventional hip and knee arthroplasty revealed significant differences in several outcomes. Patients who underwent robotic-assisted surgery had a shorter median hospital stay (1 day, IQR: 1-1) compared to the conventional approach (2 days, IQR: 2-2) ($p < 0.001$). Notably, patients in the robotic group reported lower postoperative VAS (median of 0, IQR: 0-1) compared to the conventional group (median of 1, IQR: 0-2) ($p = 0.0449$) (table 1).

Table 1 - Demographic and Perioperative Characteristics of Patients Undergoing Conventional and Robotic Hip and Knee Arthroplasty

Variable	Category	Conventional n = 174	Robotics n = 118	Total	<i>p</i>
Age	Median (IQR)	68.5 (63-76)	72 (66-78)	70 (64-78)	0.021
Sex	Female	105 (60.34)	78 (66.1)	183 (62.67)	0.318
	Male	69 (39.66)	40 (33.9)	109 (37.33)	
	Total	174 (100)	118 (100)	292 (100)	
Residential Area	Rural	22 (12.64)	3 (2.54)	25 (8.56)	0.002
	Urban	152 (87.36)	115 (97.46)	267 (91.44)	
	Total	174 (100)	118 (100)	292 (100)	
Diagnostic Group	Arthrosis	9 (7.56)	9 (7.83)	18 (7.69)	0.691
	Fracture	0 (0)	2 (1.74)	2 (0.85)	
	Gonarthrosis	93 (78.15)	86 (74.78)	179 (76.5)	
	Others conditions	4 (3.36)	4 (3.48)	8 (3.42)	
	Knee disorders	13 (10.92)	14 (12.17)	27 (11.54)	
	Total	119 (100)	115 (100)	234 (100)	
Pre-Surgery Planning in Days	Median (IQR)	17 (7-32)	14 (8-22)	14 (8-23)	0.6893

Post-surgical VAS	Median (IQR)	1 (0-2)	0 (0-1)	0 (0-2)	0.045
Pre-Surgery Hemoglobin	Median (IQR)	13.6 (12.7-14.5)	13.2 (12.5-14.5)	13.5 (12.5-14.5)	0.268
Post-Surgery Hemoglobin	Median (IQR)	11.75 (10.4-12.8)	11.7 (11.1-12.5)	11.7 (10.8-12.6)	0.433
Pre-Surgery VAS	Median (IQR)	1 (0-3)	0 (0-1)	0 (0-2)	0.009
Total Stay Days	Median (IQR)	2 (2-2)	1 (1-1)	2 (1-2)	< 0.001
Discharge Status	Deceased	1 (0.57)	0 (0)	1 (0.34)	0.409
	Alive	173 (99.43)	118 (100)	291 (99.66)	
	Total	174 (100)	118 (100)	292 (100)	
Body mass index (BMI)	Underweight	2 (1.23)	3 (2.68)	5 (1.82)	0.224
	Normal	45 (27.61)	17 (15.18)	62 (22.55)	
	Overweight	64 (39.26)	50 (44.64)	114 (41.45)	
	Obese 1	42 (25.11)	36 (32.14)	78 (28.36)	
	Obese 2	9 (5.52)	5 (4.46)	14 (5.09)	
	Obese 3	1 (0.61)	1 (0.89)	2 (0.73)	
	Total	163 (100)	112 (100)	275 (100)	

Legend: VAS: Visual Analog Scale

There were fewer transfusions in the robotic group (1.69%) compared to the conventional group (8.67%) ($p = 0.013$). The type of anesthesia used differed between the groups, with spinal anesthesia being more common in the conventional group (40.81%) compared to the robotic group (32.03%) ($p < 0.001$). Despite these differences, no statistically significant differences were observed in postoperative hemoglobin levels ($p = 0.4335$) or readmission proportion ($p = 0.251$) (table 2).

Table 2 - Distribution of Anesthesia Type, Transfusions, and Clinical Characteristics in Patients Undergoing Conventional and Robotic Arthroplasty

Variable	Category	Conventional	Robotics	Total	P-Value
Type of Anesthesia	General	41 (23.56)	21 (17.80)	62 (21.23)	< 0.001
	Spinal	71(40.81)	26 (22.03)	97 (33.21)	
	Spinal + Sedation	48(27.59)	66(55.93)	114(39.04)	
	General+ Sedation	13 (7.47)	5 (4.24)	18 (6.16)	
	Sedation	1(0.57)	0(0.00)	1(0.34)	
	Total	174 (100)	118 (100)	292 (100)	
Total Transfusions	No	158 (91.33)	116 (98.31)	274 (94.16)	0.013
	Yes	15 (8.67)	2 (1.69)	17 (5.84)	
	Total	173 (100)	118 (100)	291 (100)	
Pre-Surgery Transfusion	No	167 (96.53)	118 (100)	285 (97.94)	0.041
	Yes	6 (3.47)	0 (0)	6 (2.06)	
	Total	173 (100)	118 (100)	291 (100)	
Post-Surgery Transfusion	No	164 (94.8)	116 (98.31)	280 (96.22)	0.123
	Yes	9 (5.2)	2 (1.69)	11 (3.78)	
	Total	173 (100)	118 (100)	291 (100)	
Regional Blockade	No	14 (8.05)	4 (3.39)	18 (6.16)	0.105
	Yes	160 (91.95)	114 (96.61)	274 (93.84)	
	Total	174 (100)	118 (100)	292 (100)	
Post-Surgical Analgesics	No	5 (2.87)	2 (1.69)	7 (2.4)	0.518
	Yes	169 (97.13)	116 (98.31)	285 (97.6)	
	Total	174 (100)	118 (100)	292 (100)	
Post-Surgical Opioids	No	9 (5.17)	6 (5.08)	15 (5.14)	0.973
	Yes	165 (94.83)	112 (94.92)	277 (94.86)	
	Total	174 (100)	118 (100)	292 (100)	
Post-Surgical NSAIDs (Aine)	No	42 (24.14)	17 (14.41)	59 (20.21)	0.040
	Yes	132 (75.86)	101 (85.59)	233 (79.79)	
	Total	174 (100)	118 (100)	292 (100)	
Antibiotic Prophylaxis	No	4 (2.3)	1 (0.85)	5 (1.71)	0.348
	Yes	170 (97.7)	117 (99.15)	287 (98.29)	
	Total	174 (100)	118 (100)	292 (100)	

Antithrombotic Prophylaxis	No	16 (9.2)	4 (3.39)	20 (6.85)	0.054
	Yes	158 (90.8)	114 (96.61)	272 (93.15)	
	Total	174 (100)	118 (100)	292 (100)	
Readmission	No	159 (91.38)	112 (94.92)	271 (92.81)	0.251
	Yes	15 (8.62)	6 (5.08)	21 (7.19)	
	Total	174 (100)	118 (100)	292 (100)	

A Kaplan-Meier analysis comparing hospital length shows that conventional surgery was associated with a higher proportion of patients experiencing prolonged hospital stays compared to robotic surgery. The probability of remaining hospitalized by day 5 was 13.87% (95% CI: 9.22–19.46) for the conventional surgery group, compared to 2.56% (95% CI: 0.69–6.72) for the robotic surgery group. The log-rank test indicates a p-value < 0.001, demonstrating that the difference in hospital length of stay between the two groups was statistically significant (fig.).

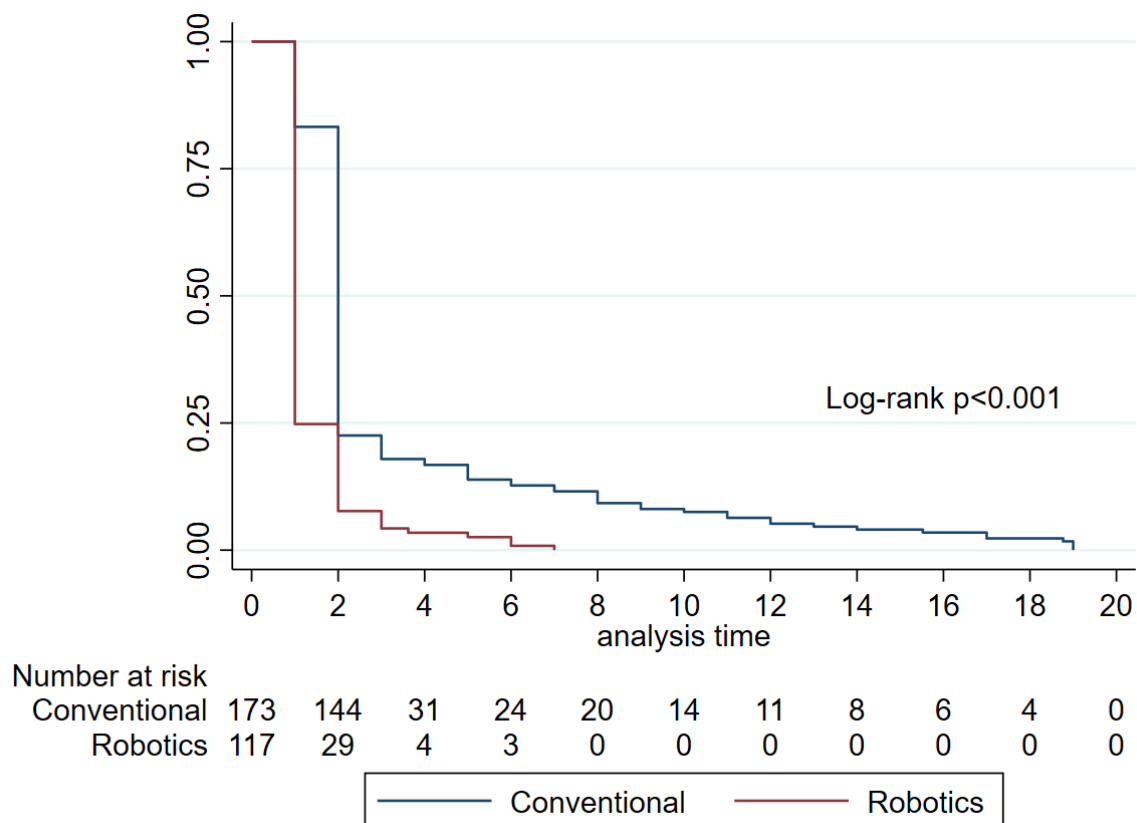


Fig. – Comparative Analysis of Length of Hospital Stay between Conventional and Robotic Surgery in Hip and Knee Arthroplasties.

A shorter hospital stay was associated with a higher likelihood of having undergone robotic-assisted surgery (OR: 0.41; 95% CI: 0.28-0.61; $p < 0.001$). Patients residing in urban areas had a significantly greater likelihood of receiving robotic surgery compared to those living in rural areas (OR: 4.83; 95% CI: 1.37-17.06; $p = 0.014$). The logistic regression model demonstrated good discriminatory ability, with an area under the ROC curve (AUC) of 0.79 (table 3).

Tabla 3 - Regression Analysis of Characteristics Associated with Receiving Robotic-Assisted Surgery

Variable	OR	95% CI	p-value
Length of Stay (days)	0.41	0.28-0.61	< 0.001*
Urban Zone (vs. Rural)	4.83	1.37-17.06	0.014*

Legend: OR = Odds Ratio; CI = Confidence Interval; * $p < 0.05$ considered statistically.

Discussion

The results of this study reveal significant differences between conventional surgery and robot-assisted surgeries for hip and knee arthroplasty. Several key findings are worth noting: although robotic surgery had a longer average operative time, patients who underwent this type of intervention experienced shorter hospital stays, which is associated with reduced exposure to nosocomial infections and lower hospital costs, benefiting both the patient and the healthcare system.⁽¹⁶⁾ Additionally, robotic surgery was associated with reduced postoperative VAS, suggesting potential advantages in terms of less surgical trauma and, consequently, earlier functional recovery.⁽¹⁷⁾

Despite these benefits, the longer operative time in the robotic surgery group may represent a disadvantage in terms of resource use.⁽¹⁸⁾ However, the observed advantages of shorter hospital stays and reduced postoperative VAS may offset this aspect, as a faster recovery could translate into lower demand for postoperative care resources and earlier return to daily activities for patients.⁽¹⁹⁾

These findings align with B. Cayani's analysis, which demonstrated that robotic surgery is associated with quicker functional recovery, taking into account factors such as a reduced number of physical therapy sessions compared to conventional arthroplasty.⁽²⁰⁾

Another notable finding is the age difference between the groups, with patients in the robotic group being older. While this might suggest that robotic surgery could be especially beneficial in older adults due to its association with quicker and less painful recovery, this interpretation should be made with caution. Since the study was observational and non-randomized, and no age-stratified analysis was performed, the possibility of selection bias cannot be ruled out. Therefore, causality between age and surgical outcomes should not be inferred. Future studies should include stratified or adjusted analyses to explore whether older patients benefit more significantly from robotic-assisted procedures

Regarding hemoglobin levels, the robotic surgery group had a lower rate of transfusions, suggesting that these procedures tend to be less invasive and, therefore, associated with less intraoperative blood loss compared to conventional surgeries. This translates into better preservation of postoperative hemoglobin levels, which is crucial for a faster recovery with fewer complications. Despite these differences, no statistically significant differences were observed in postoperative hemoglobin levels or readmission rates, indicating appropriate management in both approaches.⁽²¹⁾

Finally, the differences in residence (urban area) between the groups are also noteworthy. The higher prevalence of urban patients in the robotic surgery group may reflect greater availability of this technology in hospitals located in urban areas or a stronger inclination among urban patients to opt for technologically advanced procedures. However, this finding also highlights deeper systemic barriers within Latin American healthcare systems, where structural inequalities—such as the centralization of high-complexity services in urban centers, limited technological infrastructure in rural areas, and unequal allocation of healthcare resources—hinder equitable access to surgical innovations. Bridging this urban–rural gap will require not only technological investment but also policy-level interventions to promote

decentralization, improve healthcare infrastructure, and ensure equitable distribution of medical innovations across regions.^(22,23)

This study has some limitations. It was conducted at a single high-complexity institution, and the exclusion criteria, particularly for patients with certain comorbidities, may introduce selection bias. Furthermore, the reliance on retrospective data from electronic medical records may have resulted in incomplete or inaccurate data capture. Additionally, the study did not include a medium-term follow-up, which limits the ability to evaluate outcomes beyond the immediate postoperative period. Finally, the relatively short follow-up period restricts the assessment of long-term outcomes such as prosthetic survival and functional recovery. These results, while consistent with previous findings, provide valuable evidence from a Latin American context, an underrepresented setting in the literature highlighting the clinical relevance and applicability of robotic surgery across diverse healthcare systems. Future studies with longer follow-up periods, medium- and long-term assessments, multicenter designs, and detailed analyses of surgical times are recommended to validate and expand upon these findings.

Robotic-assisted arthroplasty demonstrates promising benefits, including a median reduction of one day in hospital stay, lower postoperative pain scores, and a fivefold decrease in transfusion rates (1.7 vs. 8.7%), which may contribute to faster recovery and improved early clinical outcomes. These findings suggest that robotic surgery can enhance perioperative management and potentially improve patient satisfaction and resource utilization.

However, these advantages must be weighed against challenges such as longer operative times and the high acquisition and maintenance costs of robotic systems. Therefore, future research should prioritize multicenter studies with medium- and long-term follow-up, as well as robust cost-effectiveness analyses, to assess the sustainability and broader applicability of robotic-assisted joint replacement in diverse healthcare settings, particularly in low- and middle-income countries.

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Conflict of de interest

The authors declare that they have no conflict of interest.

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