Research Square

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Is ROSA Always Reliable? High Accuracy but Notable Deviations in Medial Tibial Resection and Femoral Component Sizing in Mechanically-Aligned Total Knee Arthroplasty

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Research Article

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Abstract

Background

The ROSA (Robotic Surgical Assistant) Knee system (Zimmer Biomet, Indiana, USA) has been developed to enhance the precision of bone resections and alignment in total knee arthroplasty (TKA). We evaluated the accuracy of intraoperative ROSA Knee System values compared with actual bone resections, as well as alignment and clinical outcomes, under a standardized mechanical alignment protocol.

Methods

This study was a retrospective analysis of prospectively collected data from 123 consecutive primary TKAs performed from January 2022 to October 2024. Actual bone resections were compared with corresponding ROSA values: validated intraoperative values for distal femur (DF) and proximal tibia (PT) and preoperatively planned values for posterior femoral condyles (PF). Mechanical alignment was assessed preoperatively and 1 year postoperatively using full-length radiographs to measure the hip-knee-ankle (HKA) angle. Clinical outcomes and range of motion were evaluated using the Knee Society Score and goniometric measurements at baseline and 3 months, 6 months, 1 year, and 2 years postoperatively.

Results

Postoperative HKA angle was 1.65 ± 1.52°. No significant differences were observed in medial and lateral DF, PF, and lateral PT or extension and flexion gaps (all $p > 0.05$). However, the medial proximal tibial bone resection thickness was significantly greater in the ROSA values than in the actual values (3.88 ± 1.88 mm vs 2.61 ± 1.70 mm, $p < 0.001$). the mean difference in femoral component size was 1.13 ± 0.48 ($p < 0.001$). Significant improvements were observed in knee motion, with flexion contracture decreasing from 10.81° to 2.39° and range of motion increasing from 120.00° to 138.99° at the final follow-up. Functional outcomes also improved, as indicated by improved Knee Society Scores and Hospital for Special Surgery score ($p < 0.001$).

Conclusions

The ROSA Knee System provides accurate alignment, gap balancing, and bone resection. Surgeons should verify resection thickness and component sizing intraoperatively, particularly for medial tibial resection and femoral sizing. Nevertheless, ROSA remains a reliable tool in robotic-assisted TKA.

Background

Total knee arthroplasty (TKA) is frequently performed to control pain, restore function, and enhance the quality of life for patients with end-stage osteoarthritis [1]. However, 10–20% of patients report dissatisfaction after surgery and continue to experience post-operative pain and functional limitations [2, 3]. Precise implant positioning and appropriate soft-tissue balance are essential for achieving a stable, functional, and durable knee after TKA. Inaccuracies in these factors may contribute to persistent pain, instability, and early failure [4, 5].

Robotic-assisted total knee arthroplasty (RA-TKA) enables more precise and accurate bone resection, reduces errors, and provides a personalized approach to TKA [6]. However, the evidence for each robotic system in RA-TKA varies in quality and quantity, requiring individual assessment based on specificity [6].

The RObotic Surgical Assistant (ROSA) Knee System (Zimmer Biomet, Warsaw, IN, USA) is a novel, robotic TKA system that supports surgeons in performing highly accurate and reproducible surgeries. The system provides intraoperative feedback that aids in restoring joint kinematics and optimizing soft-tissue balance [7]. Despite the reported benefits of the ROSA Knee System, including precise bone resections, accurate limb alignment, and low early revision rates [7, 8], Shin *et al.* highlighted unsatisfactory accuracy in the sagittal positioning of the tibial component [9]. There is a paucity of literature robustly validating the accuracy of the ROSA Knee System's intraoperative target values for specific bone resection thicknesses and optimal component sizing against actual measured values. Therefore, further research is warranted to clarify the true accuracy of intraoperative target values compared with postoperative radiographic measurements and validate associated clinical and patient-reported outcomes.

Accordingly, the aim of this study was to evaluate the accuracy and reliability of the ROSA Knee System by comparing intraoperatively measured and actual postoperative outcomes, including bone resection thickness, gap balance, limb alignment, and femoral component sizing. We hypothesized that the ROSA Knee System would demonstrate high accuracy and consistency in bone resections, balanced flexion–extension gaps, and appropriate femoral component sizing, leading to accurate mechanical alignment following TKA.

Methods

Patient recruitment

This study was a retrospective analysis of prospectively collected data from primary robotic-assisted TKAs performed from January 2022 to October 2024 by a single surgeon at a single center. TKA was performed in patients with knee osteoarthritis who met the eligibility criteria, as defined by the Health Insurance Review & Assessment Service in Korea. Patients who underwent primary robotic-assisted TKA using the ROSA Knee System for primary osteoarthritis between January 2022 and October 2024, with a minimum follow-up of 2 years, were included.

Surgical procedures and rehabilitation

All surgeries were performed in the supine position under spinal or general anesthesia. A medial parapatellar approach was used in all cases. The PERSONA (Zimmer Biomet, Warsaw, IN, USA) posterior-stabilized implant was utilized with cement fixation. Additional pin site incisions were made for femoral and tibial pin fixation in all TKAs. Two femoral pins (3.2-mm diameter) were positioned in the proximal wound in the femur anterior cortex, and two tibial pins (3.2-mm diameter) were positioned in the distal wound in the anteromedial tibial crest.

All patients underwent TKA using the imageless ROSA Knee System, which comprises robotic and optical units, aiming to achieve mechanical alignment. All procedures were performed by a Zimmer Biomet-qualified surgeon following the standard ROSA protocol, using a modified gap technique in which distal femoral resection was completed first, followed by proximal tibial resection. After bone resections, actual flexion and extension gaps were evaluated, and femoral rotation was determined based on the gap balance assessment. Additional anterior and posterior femoral cuts were subsequently performed as required [10–13]. Quadriceps muscle exercises were initiated on postoperative day 1 for all patients, and continuous passive motion and partial weight-bearing ambulation using a walker were allowed to start on postoperative day 2.

Assessment of alignment

Alignment was assessed preoperatively and at 1 year postoperatively using weight-bearing, full-length radiographs to measure the hip–knee–ankle (HKA) angle. In addition, medial proximal tibial angle (MPTA) and lateral distal femoral angle (LDFA) were measured to evaluate deformity correction.

Assessment of bone resections, gaps, and femur size

Bone resections of the distal femur (DF), posterior femoral condyles (PF), and proximal tibia (PT) were performed according to the ROSA guide. The thickness of the resected bones, registered as ROSA points, was measured with a caliper. Comparisons were made with the corresponding ROSA values: validated intraoperative values for the medial and lateral DF and PT and preoperatively planned values for PF (Fig. 1). As the ROSA measures the intraoperative gap after inserting the trial component, the displayed values were adjusted to account for the implant design before comparison. After bone resection, flexion and extension gaps were measured using an offset-type, force-controlled, spreader system (Aesculap, B. Braun, Tuttlingen, Germany) under a constant force of 150 N, and the corrected ROSA-derived values were compared with the spreader measurements. The actual size of the femoral component was determined using a femur sizer and compared with the femoral size predicted by ROSA, which does not provide tibial sizing or distinguish between standard and narrow femoral options.

Assessment of clinical outcomes

All eligible patients were assessed for range of motion, which was evaluated in terms of flexion contracture and further flexion, using a goniometer and physical examination by an orthopedic surgeon. Subsequently, two patient-reported outcome measures were completed, the Knee Society Score (2011) and the Hospital for Special Surgery score. These assessments were compared with preoperative values and repeated at 3 months, 6 months, 1 year, and 2 years postoperatively. Clinical scores were obtained using patient interviews with the same standardized method.

Data analyses

All data are expressed as mean ± standard deviation. Kolmogorov–Smirnov and Shapiro–Wilk tests were used to examine the normal distribution of the data. Measurements were compared using an independent Student's *t*-test or the Mann–Whitney U-test, paired *t*-test, and Wilcoxon signed-rank test. For clinical assessment outcomes at various time points, repeated-measures analysis of variance was used. All statistical analyses were conducted using the Statistical Product and Service Solutions software (SPSS) (version 27.0, IBM, Armonk, NY), and the threshold of statistical significance was set at $p < 0.05$.

Results

In total, 325 TKAs were performed by a single surgeon at our institution. After applying the inclusion criteria—primary robotic-assisted TKA with a minimum 2-y follow-up—123 cases were included in the study (Fig. 2; Table 1).

Table 1
Patient demographics

All cases	**Overall**
	123 (100%)
Sex	
Men	24 (19.5%)
Women	99 (80.5%)
Age (years)	70.08 ± 6.10
Weight (kg)	65.43 ± 12.03
Height (cm)	155.79 ± 12.03
BMI (kg/m^2)	26.88 ± 3.80
Surgical side	
Right	64 (52.03%)
Left	60 (48.77%)

Values are presented as n (%) or mean ± SD. BMI, body mass index; SD, standard deviation

Weight-bearing, full-length radiographs were used to compare alignment changes preoperatively and at 1 year postoperatively. The HKA angle changed from 7.58° ± 5.97° to 1.65° ± 1.52° ($p < 0.001$), whereas the MPTA and LDFA angles were corrected from 84.41° ± 2.62° to 89.79° ± 2.08° ($p < 0.001$) and from 89.29° ± 3.08° to 89.9° ± 1.79° ($p = 0.030$), respectively.

The DF medial resection was 8.50 ± 1.47 mm, and the ROSA value was 8.45 ± 1.67 mm ($p = 0.811$). The lateral side measured 8.07 ± 1.85 mm vs. 8.23 ± 2.24 mm with ROSA ($p = 0.513$). The PF medial resection was 10.62 ± 1.97 mm vs. 10.40 ± 2.26 mm with ROSA ($p = 0.428$), and the lateral side was 7.84 ± 1.77 mm vs. 7.90 ± 1.31 mm with ROSA ($p = 0.410$). The PT medial resection was 2.61 ± 1.70 mm vs. 3.88 ± 1.88 mm with ROSA ($p < 0.001$). The lateral side was 8.39 ± 2.33 mm vs. 8.49 ± 1.94 mm with ROSA ($p = 0.730$) (Table 2).

Table 2
Comparison of bone resection measurements with caliper and ROSA validation values

Bone resection	Measured value		Mean differences	*p*-value
	Actual	ROSA		
Distal Femur				
Medial	8.50 ± 1.47	8.45 ± 1.67	-0.05 ± 1.21	$p = 0.811^{+}$
Lateral	8.07 ± 1.85	8.23 ± 2.24	0.15 ± 1.41	$p = 0.513^{-}$
Posterior Femoral Condyle				
Medial	10.62 ± 1.97	10.40 ± 2.26	-0.21 ± 1.72	$p = 0.428^{+}$
Lateral	7.84 ± 1.77	7.90 ± 1.31	0.05 ± 1.37	$p = 0.410^{-}$
Proximal Tibia				
Medial	2.61 ± 1.70	3.88 ± 1.88	1.27 ± 1.61	$p < 0.001^{+}$
Lateral	8.39 ± 2.33	8.49 ± 1.94	0.09 ± 1.67	$p = 0.730^{+}$

Values are presented as mean ± SD. *P* values were derived from $^{+}$independent Student's *t*- and $^{-}$Mann–Whitney U-test; Kolmogorov–Smirnov and Shapiro–Wilk tests were used to check for normality of data distribution

ROSA, RObotic Surgical Assistant; SD, standard deviation

The medial extension gap was 21.72 ± 2.26 mm, and the ROSA-derived value was 22.01 ± 1.86 mm ($p = 0.406$). The lateral side measured 21.73 ± 1.77 mm vs. 22.03 ± 1.64 mm with ROSA ($p = 0.175$). The medial flexion gap was 21.78 ± 1.78 mm vs. 21.99 ± 1.68 mm with ROSA ($p = 0.337$). The lateral side measured 21.80 ± 1.71 mm vs. 22.07 ± 1.79 mm with ROSA ($p = 0.231$) (Table 3).

Table 3
Comparison of bone resection measurements with tensioner and ROSA validation values

	Measured value		Mean differences	*p*-value
	Actual	**ROSA**		
Extension Gap				
Medial	21.72 ± 2.26	22.01 ± 1.86	0.28 ± 1.46	$p = 0.406^{-}$
Lateral	21.73 ± 1.77	22.03 ± 1.64	0.30 ± 1.34	$p = 0.175^{+}$
Flexion Gap				
Medial	21.78 ± 1.78	21.99 ± 1.68	0.21 ± 1.28	$p = 0.337^{+}$
Lateral	21.80 ± 1.71	22.07 ± 1.79	0.27 ± 1.43	$p = 0.231^{+}$

Values are presented as mean ± SD. *P*-values were derived from $^{+}$independent Student's *t*- and $^{-}$Mann–Whitney U-tests; Kolmogorov–Smirnov and Shapiro–Wilk tests were used to check for normality of data distribution.

ROSA, RObotic Surgical Assistant; SD, standard deviation

The actual femoral component size measured using a manual femur sizer was 6.80 ± 1.57, whereas the size predicted by the ROSA system was 7.93 ± 1.59; the mean difference in femoral component size was 1.13 ± 0.48 ($p < 0.001$) (Table 4).

Table 4
Comparison of femoral component size measurements with sizer and ROSA predictions

	Measured value		Mean differences	*p*-value
	Actual	**ROSA**		
Femur Size	6.80 ± 1.57	7.93 ± 1.59	1.13 ± 0.48	$p < 0.001$

Values are presented as mean ± SD; *p*-values were derived from paired *t*-tests

ROSA, RObotic Surgical Assistant; SD, standard deviation

The mean flexion contracture improved from a preoperative value of 10.81 ± 7.53° to 2.39 ± 2.44° at the final follow-up. The mean further flexion increased from 130.81 ± 15.14° before surgery to 140.98 ± 9.14° 2-y postoperatively ($p < 0.001$). Consequently, the overall range of motion improved from 120.00 ± 14.37° to 138.99 ± 9.75°. Both the Knee Society knee score and function score demonstrated improvement, increasing from 40.72 ± 7.47 and 51.28 ± 3.49 preoperatively to 89.93 ± 4.10 and 82.41 ± 6.01,

respectively, at the final follow-up ($p < 0.001$). Similarly, the Hospital for Special Surgery score improved from 52.94 ± 6.35 to 92.54 ± 5.82 ($p < 0.001$) (Table 5).

Table 5
Clinical outcomes of the ROSA Knee System TKA

	Time point	Measured value	*p*-value	
			vs. Preoperative	Overall
KS-KS	Preoperative	40.72 ± 7.47	-	
	3 months	78.63 ± 7.22	< 0.001	< 0.001
	6 months	87.31 ± 5.57	< 0.001	
	1 year	91.32 ± 3.08	< 0.001	
	2 years	89.93 ± 4.10	< 0.001	
KS-FS	Preoperative	51.28 ± 3.49	-	
	3 months	64.89 ± 3.52	< 0.001	< 0.001
	6 months	73.90 ± 5.22	< 0.001	
	1 year	82.30 ± 4.56	< 0.001	
	2 years	82.41 ± 6.01	< 0.001	
HSS	Preoperative	52.94 ± 6.35	-	
	3 months	76.62 ± 6.74	< 0.001	< 0.001
	6 months	85.50 ± 5.76	< 0.001	
	1 year	91.12 ± 4.99	< 0.001	
	2 years	92.54 ± 5.82	< 0.001	

Values are presented as mean ± SD; *p*-values were derived from repeated-measures analysis of variance

HSS, Hospital for Special Surgery; KS-FS, Knee Society function score; KS-KS, Knee Society knee score; ROSA, RObotic Surgical Assistant; SD, standard deviation; TKA, Total knee arthroplasty

Discussion

RA-TKA is gaining popularity for enhancing surgical accuracy and precision and enabling more personalized alignment in TKA [14–16]. In the current study, the ROSA Knee System demonstrated high accuracy in alignment and gap balance; of the resection measurements, only medial PT differed between actual and validation values, whereas medial and lateral DF, PF, and lateral PT resections were accurate. However, the system tended to overestimate femoral component size.

Robotic assistance can consistently and accurately restore alignment within 3° of the neutral mechanical axis [17]. Rossi *et al.* evaluated 75 patients treated with the ROSA Knee System and found that the HKA angle improved from 178.8° ± 8.6° to 179.0° ± 1.3°, with a mean difference of 1.2° ± 1.1° between the planned and measured values [18]. In the current study, the HKA angle improved from 7.58° ± 5.97° to 1.65° ± 1.52° ($p < 0.001$), confirming the high accuracy of the alignment correction with the ROSA Knee System.

Gamie *et al.* evaluated the accuracy of resection values using the ROSA Knee System in 44 patients, and caliper measurements of the DF, PT, and PF were obtained [10]. The differences between the planned and actual resection depths were 0.67 ± 0.6 mm ($p = 0.217$) and 0.94 ± 1.15 mm ($p = 0.4$) for the medial and lateral DF; 0.93 ± 0.81 mm ($p = 0.001$) and 0.89 ± 0.8 mm ($p = 0.008$) for the medial and lateral PT; and 1.1 ± 0.97 mm ($p = 0.001$) and 1.04 ± 0.79 mm ($p = 0.001$) for the medial and lateral PF, respectively. Gamie *et al.* demonstrated that the imageless mode of the ROSA Knee System was highly accurate, with mean differences between the planned and actual caliper measurements of 0.67–1.1 mm for the DF, PT, and PF resections. Although some cuts showed 0-mm mean difference between the planned and actual values, discrepancies of several millimeters were also observed. Medial tibial plateau and posterior femoral condyle resections demonstrated greater variability than distal femoral resections [10]. Unlike the study by Gamie *et al.*, which adopted a functional-alignment protocol, the present study followed a mechanical-alignment approach, facilitating a direct evaluation of bone resection accuracy under standardized mechanical alignment conditions.

The discrepancy observed exclusively in medial PT resection thickness warrants consideration. Imageless robotic systems rely on intra-articular surface registration, often assuming uniform cartilage thickness [19]. However, the majority of patients with TKA in the Asian demographic present with advanced varus deformity and severe medial compartment osteoarthritis, leading to extreme cartilage wear on the medial PT [20]. Consequently, the robotic probe may register directly on subchondral bone, creating a discordance with actual caliper measurements of the resected bone. This anatomical reality explains the localized deviation and underscores the importance of independent surgeon verification for medial PT resections.

Gap balancing has traditionally relied on the surgeon's intuition and experience, which is subjective and can be variable [21]. Objective assessment and control of the gap using robotic assistance could potentially result in a knee that feels more natural, thereby improving patient satisfaction [10]. Wong *et al.* reported that when using the MAKO system, gap-balancing analysis indicated minimal differences, with only one case (0.6%) showing a medial–lateral gap difference of ≥ 3 mm in extension and three cases (1.9%) in flexion. The mean flexion and extension gaps were 18.36 ± 1.1 and 18.29 ± 1.3 mm, respectively, and the vast majority (98.1%) of knees exhibited a gap difference of ≤ 2 mm [22]. Similarly, in the current study, no differences in extension and flexion were observed between the medial and lateral gaps.

In the current study, femoral component size differed between ROSA predictions and intraoperative measurements, likely due to anatomical differences between Asian and Caucasian femurs. Yue *et al*. reported smaller mediolateral and anteroposterior dimensions in Chinese females (72.8 ± 2.6 and 58.8 ± 2.5 mm, respectively) than in White females (76.4 ± 4.0 and 59.7 ± 2.6 mm, respectively; $p = 0.002$). Similarly, Chinese males showed smaller mediolateral (82.6 ± 3.6 vs. 86.0 ± 5.6 mm; $p = 0.028$) and anteroposterior dimensions (65.0 ± 2.8 vs. 67.5 ± 3.6 mm; $p = 0.017$) [23].

This study had some limitations. First, the retrospective single-center design may limit generalizability and introduce selection bias [24]. Second, achieving accurate pointer registration may be difficult, and potential cartilage penetration can occur in areas like the posterior condyles that are hard to access, especially when adequate flexion is limited. Despite these limitations, the findings of this study remain clinically meaningful, as they highlight specific areas where surgeons should exercise caution when relying on RA-TKA.

Conclusions

Although the ROSA Knee System demonstrated high accuracy in alignment restoration, gap balancing, and most bone resections, discrepancies were observed in medial proximal tibial resection thickness and femoral component sizing accuracy. Therefore, surgeons must independently verify resection thicknesses and component selection intraoperatively to optimize implant fit and prevent unintended over-resection. Nevertheless, the system provided reliable alignment correction and meaningful functional improvement, supporting its role as a reproducible and useful tool in contemporary TKA.

Abbreviations

DF, distal femur; HKA, hip-knee-ankle; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; PF, femoral condyles; PT, proximal tibia; RA-TKA, Robotic-assisted total knee arthroplasty; ROSA, RObotic Surgical Assistant; TKA, total knee arthroplasty

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board (IRB) of Pusan National University Yangsan Hospital (IRB No. 55-2025-145). The requirement for informed consent was waived due to the retrospective nature of the study.

Clinical trial number

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare no conflicts of interest associated with this manuscript.

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Authors' contributions

Sang-Min Lee: Conceptualization, Data curation, Project administration, Resources, Supervision, Writing – review & editing.

Jung Shin Kim: Conceptualization, Data curation, Formal analysis, Writing – original draft.

Kuen Tak Suh: Supervision.

Lih Wang: Conceptualization, Supervision, Visualization.

Kyeong Baek Kim: Formal analysis, Investigation

Won Chul Shin: Methodology, Project administration, Supervision.

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Figures

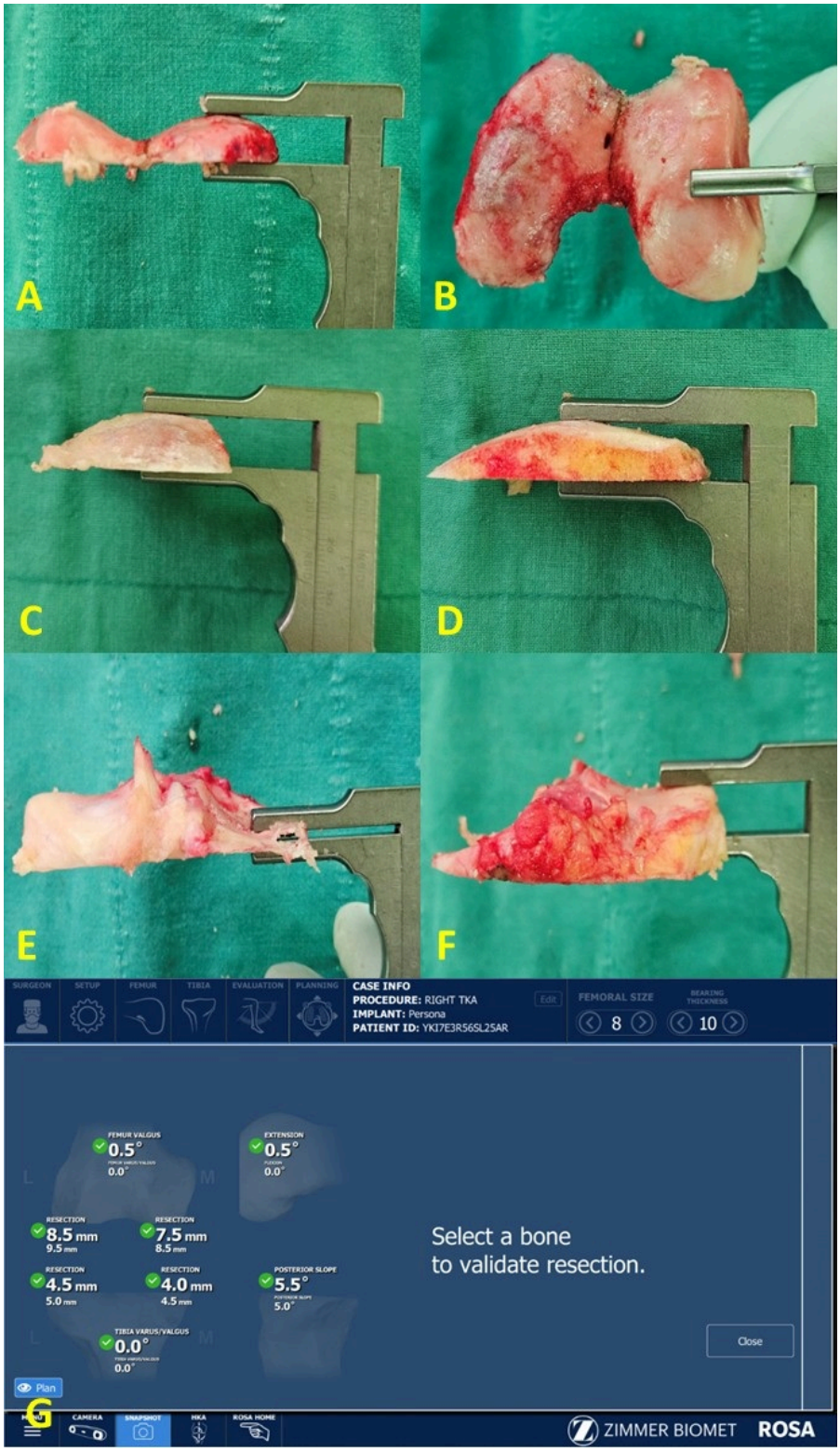


Figure 1

Caliper measurements of the resected bones. (a) Measurement of the ROSA-registered point on the medial distal femur resection. (b)Measurement of the ROSA-registered point on the lateral distal femur resection. (c) Measurement of the ROSA-registered point on the medial posterior condyle resection. (d) Measurement of the ROSA-registered point on the lateral posterior condyle resection. (e) Measurement of the ROSA-registered point on the medial proximal tibia resection. (f) Measurement of the ROSA-

registered point on the lateral proximal tibia resection. (g) Validation values of the ROSA Knee System after bone resections. ROSA, RObotic Surgical Assistant

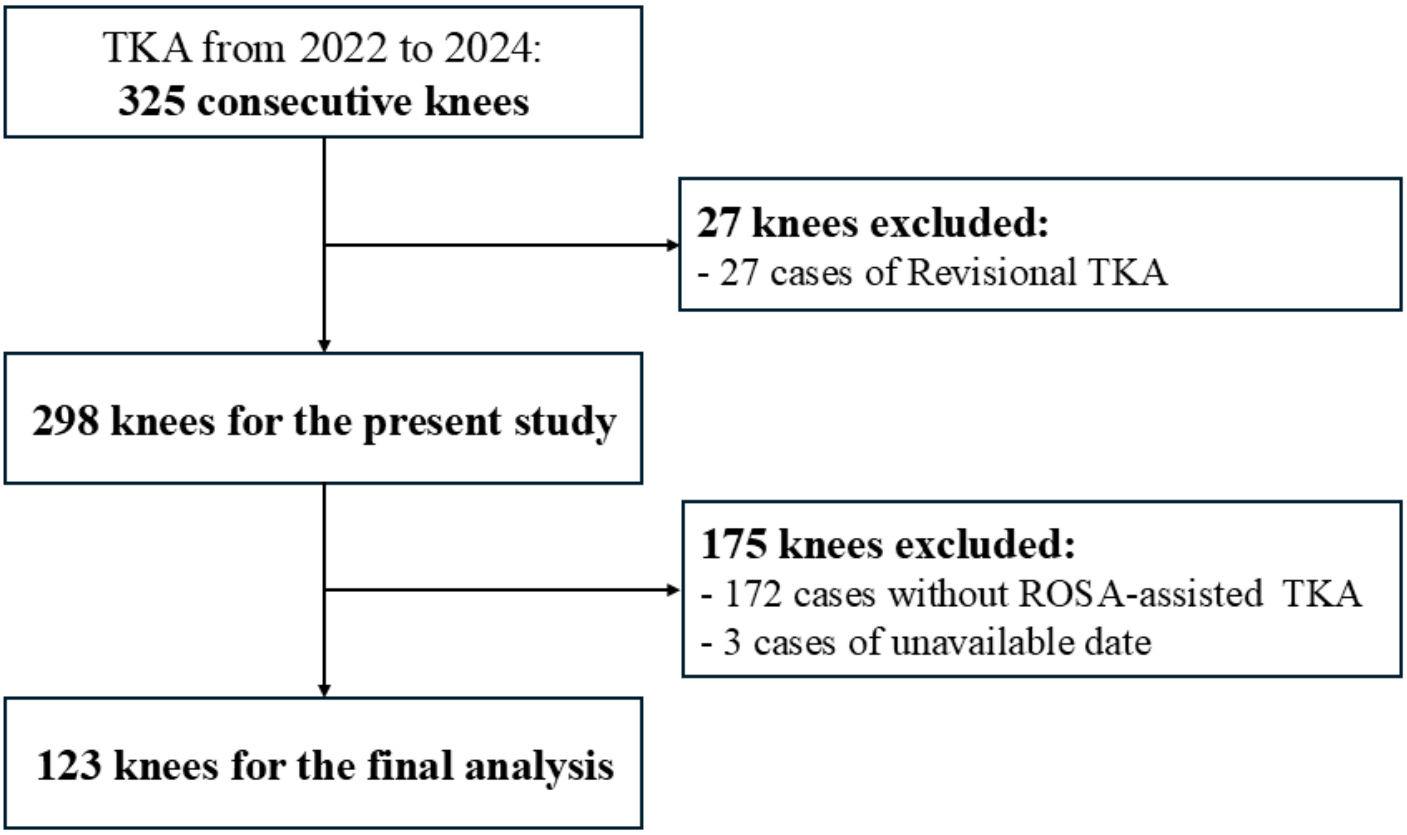


Figure 2

Flowchart of patient recruitment for this study. TKA, Total knee arthroplasty