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Long-term outcomes, satisfaction, and survival rates of a medial pivot knee design

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A B S T R A C T

Background: The aim of this study was to evaluate the long-term clinical outcomes, satisfaction, perceived joint stability, and survival rates following medial pivot TKA.
Methods: Data from TKAs performed at a single institution between 2008 and 2014 were retrospectively reviewed. Patients without consent were excluded. Inclusion: medial pivot TKA surgery. All patients received the same cemented Microport Advanced® and Evolution® Medial Pivot Knee System. Data collection comprised clinical and radiological outcomes, time of failure and/or death, surgical techniques (measured resection (MR) femur first technique following mechanical alignment principles vs. gap balancing (GB) tibia first technique preserving preoperative varus deformity up to 4°). Kaplan–Meier survival analysis compared survival between surgical techniques. Logistic regression evaluated surgical technique as a predictor for revision status. Risk analysis calculated relative and absolute risk differences between surgical techniques.
Results: Of the 137 patients included in the final analysis, there were 24 deaths (17.5%), 15 lost to follow up (10.9%), four revisions (2.9%). The final follow up was obtained for 94 patients (68.6%) without revision. The mean survival was 16.14 years (95% CI: 15.96–16.32; standard error = 0.93) at the final follow up with a median of 11.32 years (IQR, 9.57–14.04). The Kaplan–Meier/Mantel–Cox indicated no difference in survival between MR and GB (Chi-squared = 0.02, P = 0.876). No other predictors for revision were found (CPAK (P = 0.78), aHKA (P = 0.55), MPTA (P = 0.73)). Nine (6.6%) patients stated that they were not satisfied with no difference for surgical technique (Chi-squared = 0.59, P = 0.824).
Conclusions: The overall mean survival time was estimated to be 16.14 years with 97% survival rate.

1. Introduction

Total knee arthroplasty (TKA) has proven highly effective for treating degenerative knee diseases, with well-documented long-term outcomes across various prosthetic designs [1].

The medial pivot design emerged from biomechanical research demonstrating that natural knee kinematics involve the lateral femoral condyle pivoting around a relatively stable medial condyle [2,3]. The lateral condyle generally pivots around an almost stationary medial condyle, functioning similarly to a ball-and-socket joint, as the lateral condyle moves forward

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and backward, rotating around the medial center [4–6]. The medial pivot TKA prosthesis mimics the natural knee motion using an asymmetric design where the medial side serves as a stable pivot point, and the lateral side allows for rolling and gliding [7,8].

Two primary surgical philosophies have emerged in TKA implantation: the measured resection (MR) technique which prioritizes precise bony cuts based on anatomical landmarks followed by soft tissue adjustments and the gap balancing (GB) technique which first performs soft tissue release to guide subsequent bone resection for balanced gaps [9,10].

Previous studies have reported the long-term clinical outcomes of medial pivot TKA, extending beyond 13 years [2,3]. Additional data is available for the mid- to long-term period, particularly at the 10-year mark, showing a revision rate of 1.9% [11].

While some long-term data are available regarding the outcomes of medial pivot TKA, there is a notable lack of information on patient satisfaction and the differences in failure rates among various surgical technique philosophies adopted for implanting the TKA (MR vs. GB). Therefore, the aim of this study was to evaluate the long-term clinical outcomes, satisfaction, joint stability, and survival rates following medial pivot TKA to determine whether the failure rates differed based on different surgical technique.

2. Materials & methods

Retrospectively collected data of all consecutive TKAs performed at a single institution between January 2008 and December 2014 were reviewed. The study adhered to the principles outlined in the Declaration of Helsinki. The Local Ethics Committees reviewed the study protocol and determined that no ethical approval was required, given the purely retrospective and observational nature of the design.

Exclusion criteria were patients who withheld informed consent for participation in the study. Patients who underwent a medial pivot TKA surgery aged 18 years old or older were included. Consequently, 137 knees were finally included in the study for the analysis.

The available demographic characteristics at the time of the surgery (n = 137) were recorded from the medical records (Table 1). The median value for age was 69 years (interquartile range (IQR), 63–75), arithmetic hip–knee–ankle (aHKA) -1 (IQR, -4 to 2), mechanical lateral distal femoral angle (mLDFA) 88 (IQR, 86–90), medial proximal tibial angle (MPTA) 87 (IQR, 85–89).

All patients received the same cemented Microport Advanced® and Evolution® Medial Pivot Knee System (MicroPort Knee System, Shanghai, China). The patients differed from the surgical strategy adopted for implanting the prosthesis and balancing the knee. Four surgeons followed one of two different techniques based on personal preference: a femur first MR

Table 1
Patient characteristics.

Preoperative				
CPAK	n	%		
1	33	24.1		
2	48	35.0		
3	19	13.9		
4	16	11.7		
5	15	10.9		
6	5	3.6		
9	1	0.7		
Postoperative				
	n	Median	IQR	
aHKA	113	24	−1	−2
LDFA	113	24	90	89
MPTA	113	24	89	88
KSS	94	45	195	183
OKS	94	45	44.5	37
FJS	94	45	72	54.5
EQ5D	94	44	1	0.8
CPAK	N	%		
1	5	3.6		
2	8	5.8		
4	16	11.7		
5	106	77.4		
6	2	1.5		

aHKA, arithmetical hip–knee–ankle angle; EQ5D, EuroQol 5-dimension; FJS, forgotten joint score;KSS, Knee Society Score; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; OKS, Oxford Knee Score.

technique based on mechanical alignment principles, aimed for neutral tibial alignment within 2°, with adjustments made through soft tissue release; or a tibia first GB technique, preserving preoperative varus deformity up to 4° and balancing the knee by adjusting the femoral resection to achieve a final maximum deformity alignment of 2.5° of varus [12]. The medial pivot system was used even for valgus knees aiming for a neutral alignment as the medial pivot may restore the natural medial pivot kinematics in these populations. No robotic or navigation platforms were utilized.

Between January and July 2024, all patients meeting the inclusion and exclusion criteria were contacted for a final follow up control to evaluate PROMs, satisfaction, instability perception, implant survival, and postoperative radiographic measurements. The Knee Society Score (KSS), the Oxford Knee Score (OKS), the Forgotten Joint Score (FJS) and the European Quality of Life 5 Dimensions 5 Level Version (EQ-5D) were administered [13–16]. Patients were asked to respond to the following two question "Considering all the way your total replaced knee affects you, would you say that your current state is acceptable?" and "Do you ever experience your knee feeling unstable or like it might give way, especially during daily activities such as walking, climbing stairs, or standing up?". Patients were allowed to answer with a yes/no response and a clinical examination was then performed to objectively assess for varus–valgus laxity in patients reporting subjective instability. To gather information on the TKA's survival for patients who were not available for follow up, their family members, caregivers, or general practitioners were contacted. The preoperative and postoperative coronal deformity was measured on long leg anteroposterior radiographs through the mechanical medial proximal tibial angle (mMPTA), the mLDFA, the aHKA angles and classified according to coronal plane alignment of the knee (CPAK) classification with negative HKA values meaning varus alignment of the leg [17].

2.1. Data analyses

The statistical analyses were conducted using SPSS software (IBM Corp., Armonk, NY, USA). The alpha level was set at 0.05. Median and IQRs, and frequencies and percentages were used for descriptive statistics of continuous and categorical variable respectively. Statistical analysis included Kaplan–Meier survival analysis with Mantel–Cox test to compare survival between surgical techniques. Logistic regression was performed to evaluate surgical technique as a predictor for revision status. A Cox multivariate regression assessed other potential predictors of revision. Chi-square tests compared patient satisfaction between groups. Risk analysis calculated relative and absolute risk differences between surgical techniques. All 137 knees were included in the survival analysis, including patients who died (censored at time of death), were lost to follow up (censored at last clinical examination), or underwent revision surgery. Kaplan–Meier survival analysis was conducted on the entire cohort to avoid selection bias.

3. Results

The flowchart of the included studies is displayed in Figure 1. Among the 137 patients included in the final analysis, there were 24 patients who died prior to the review (17.5%) so that they were included as censored data at the time of death. There

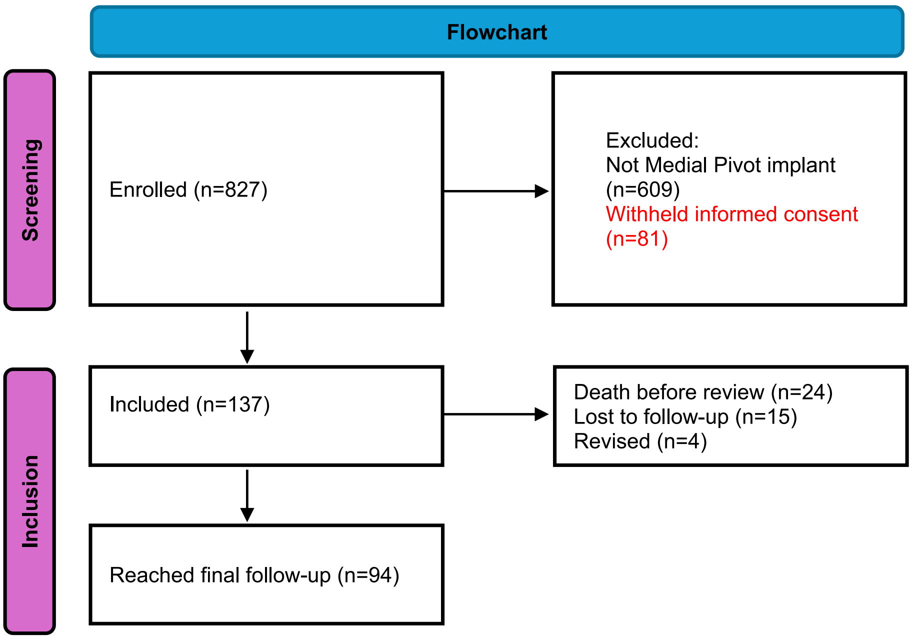

Figure 1. Flowchart of the included studies.

were 15 patients lost to follow up (10.9%) and these were included as censored data at the time of last available clinical examination. Overall, revision surgery was performed in four (2.9%) patients during the follow up period. Mechanical reasons accounted for three (2.1%) cases (total exchange for tibial aseptic loosening with progressive radiolucency lines and start-up pain), while chronic periprosthetic joint infection (PJI) accounted for one (0.7%) case which was treated with two-stage revision with articulating antibiotic loaded spacer.

The final follow up was obtained for 94 patients (68.6%) without revision. One patient developed an acute periprosthetic joint infection 8.76 years after the primary surgery. A DAIR (debridement, antibiotics, and implant retention) procedure was performed 10 days after symptom onset, followed by an aggressive 11-week course of antibiotic therapy, which successfully eliminated the need for additional surgeries. Among those recalled for the final follow up, three patients (2.1%) reported experiencing knee instability. However, the physical examination revealed no varus–valgus laxity. Despite these findings, the patients expressed overall satisfaction with their knee conditions. Non-progressive radiolucency lines were found in zones 1 and 2 on anteroposterior radiographs of the tibial component in five (3.6%) knees among those recalled for final follow up. No further complications related to the surgeries were reported in the study.

The mean survival time for the cohort was estimated to be 16.14 years (95% confidence interval (CI): 15.96–16.32; standard error (SE) = 0.93) at the final follow up with a median of 11.32 years (IQR, 9.57–14.04) (Figure 2). The Kaplan–Meier analysis with Mantel–Cox test indicated no difference in survival between patients with different surgical technique (MR vs. GB) (Chi-squared = 0.02, P = 0.876) as shown in Tables 2 and 3. In the MR group (n = 97), three revisions were observed (3.1%). In contrast, in the GB group (n = 38), one revision was observed (2.6%) with all cases being censored (Figure 3). The logistic regression model showed that the surgical technique (MR vs. GB) was not a significant predictor for revision status (B = –0.17; SE = 1.15; Wald = 0.02; dF = 1; P = 0.877; Exp(B) = 0.83; 95% CI: 0.87–8.03). A Cox multivariate found no other predictors for revision (Table 4). Of the 94 patients evaluated at the final follow up, nine (6.6%) indicated that they were not satisfied with six cases in the MR group and three in the GB group (Chi-squared = 0.59, P = 0.824). Risk analysis revealed MR at 13% higher relative risk of revision and at 0.46% higher absolute risk of revision compared with the GB group, but none of these results reached significance (Table 5).

4. Discussion

The key findings of this study were the favorable outcomes, marked by a high overall survival rate and a low revision rate. Notably, there was no significant difference in survival between the femur-first MR technique based on mechanical aligned principles and the tibia-first GB technique preserving pre-operative varus deformity used during surgery. Although our analysis showed a 13% higher relative risk of revision and a 0.46% higher absolute risk of revision in the MR group compared with the GB group, these findings did not reach statistical significance. This lack of significance should be interpreted in the context of our sample size and the low rates of revision events (only four revisions in 137 knees). While underpowered to detect small to moderate differences between surgical techniques, these trends may still have clinical relevance. The direction of

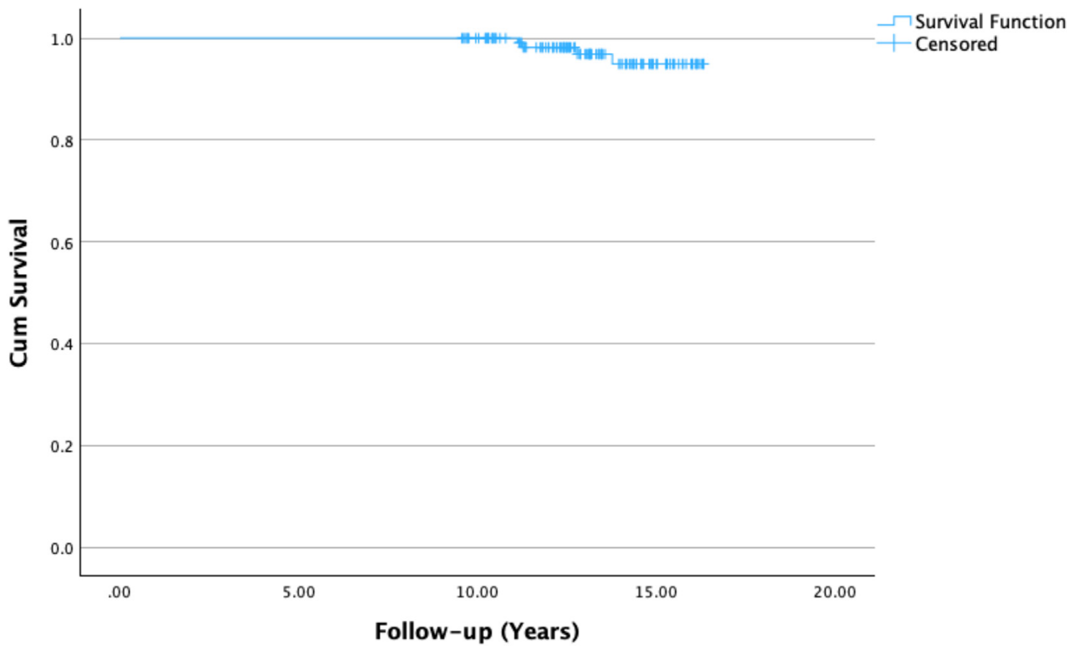

Figure 2. Overall Kaplan–Meier survival function.

Table 2
Comparison of Kaplan–Meier survival function between measured resection (MR) and gap balancing (GB) techniques.

Technique	Survival (years)	Standard Error	95% Confidence interval		Percentage (%)
			Lower Bound	Upper Bound	
MR	15.94	0.19	15.55	16.33	96.9
GB	16.00	0.31	15.40	16.61	97.4
Overall	15.98	0.16	15.66	16.31	97.0

Table 3
Comparison survival function between measured resection (MR) and gap balancing (GB) technique at mid-terms of follow up.

Years of follow up	Group	Survival (%)	95% Confidence interval		n at risk
			Lower	Upper	
5	MR	98.9	96.9	100	93
	GB	97.2	92	100	35
10	MR	96.6	92.8	100	66
	GB	97.2	92	100	26
15	MR	96.6	92.8	100	13
	GB	97.2	92	100	6

'n at risk' indicates the number of patients still being followed and 'at risk' of experiencing revision surgery.

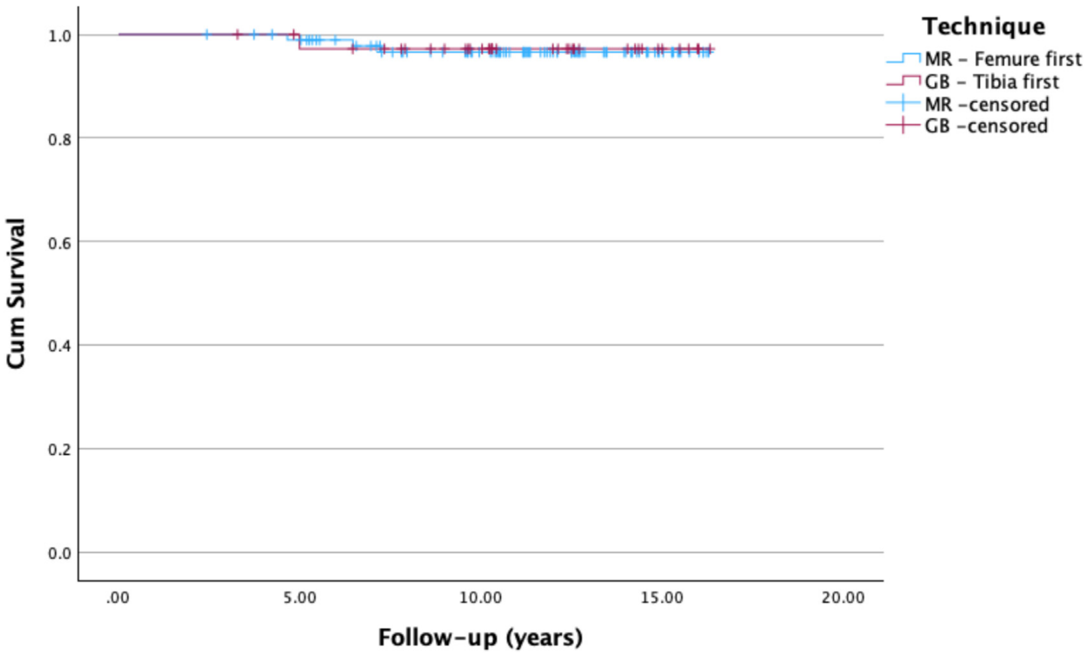

Figure 3. Comparison of Kaplan–Meier survival function between measured resection (MR) and gap balancing (GB) technique.

Table 4
Multivariate Cox proportional hazards model for risk factors associated with revision surgery.

	Hazard	Exp	SE	*Z*	*P*-value	95% Confidence Intervals	
						Lower	Upper
Surgical technique	0.06	1.06	1.23	0.05	0.96	0.0944	11.994
Postoperative CPAK	0.26	1.30	0.95	0.276	0.783	0.201	8.411
Postoperative aHKA	−0.36	0.69	0.62	−0.589	0.556	0.2024	2.362
Postoperative MPTA	0.24	1.28	0.73	0.338	0.735	0.3054	5.366

aHKA, arithmetical hip–knee–ankle angle; Exp, exponential coefficient; Hazard, hazard ratio; MPTA, medial proximal tibial angle; SE, standard error; Z, Z-score-standardized.

Table 5
Risk analysis between groups.

	Value
Absolute Risk (MR)	3.09%
Absolute Risk (GB)	2.63%
Risk Ratio (RR)	1.13
95% CI for RR	NA to 0.202
Risk Difference (RD)	0.461%
95% CI for RD	−5.68% to 6.61%
Number Needed to Harm (NNH)	217
95% CI for NNH	15.1 to 17.6
Fisher's exact test *P*-value	1

effect consistently favored the GB technique across multiple analyses, suggesting a potential biomechanical advantage of the GB approach when used with medial pivot designs.

The final follow up, conducted at a median of 11.32 years (IQR, 9.57–14.04), was successfully completed for 94 patients. During this period, revision surgery was required for four patients (2.9%), with three cases due to aseptic loosening and one case due to PJI.

The estimated mean survival time for the entire cohort was 16.14 years, indicating relatively long-term durability of the surgical outcomes. The absence of significant differences in survival between the different surgical techniques and postoperative aHKA and CPAK classes suggests that these factors do not negatively impact the long-term survival of the medial pivot prosthesis. Although the data implied that using the MR technique instead of GB on 217 patients might lead to one extra revision surgery, this estimate is highly uncertain due to the small number of revision events in both groups (Table 5). The wide confidence intervals suggest that this apparent difference between techniques may be due to chance rather than a real clinical difference.

Because preoperative clinical scores were not available, patient satisfaction levels were used to establish the clinical relevance of the postoperative scoring systems. At the final follow up, nine of the 94 patients evaluated (6.6%) reported dissatisfaction with their outcomes, with no difference observed between the groups.

In this study, three patients (2.1%) experienced mild knee instability without any varus–valgus clinical laxity, yet they reported overall satisfaction with their outcomes. No cases of sagittal instability were noted. These findings align with the expectations for the medial pivot design, which incorporates a highly congruent polyethylene insert specifically intended to enhance stability and mimic natural knee kinematics, thereby minimizing the potential for instability [18–22].

To the authors' knowledge, this is also the first study to examine the long-term survival rate in a subgroup of patients who underwent medial pivot TKAs using different surgical techniques (MR vs. GB).

Macheras et al. reported an excellent long-term clinical outcome for the same medial pivot design showing a survival analysis with a cumulative success rate of 98.8% at 17 years [2]. As with the current article, no symptomatic instability was reported in the case series. Additionally, there was an overall statistical improvement postoperatively in the case series, as indicated by the current study, which showed a high satisfaction rate at the final follow up.

Similarly, Karachalios et al. reported a Kaplan–Meier survivorship analysis with a cumulative any-reason success rate of 97.3% (95% CI: 96.7–97.9) at 10 and 15 years, respectively [3]. Finally, Jenny et al. found no difference between the 13-year survival rates of central pivot axis (98%) and medial pivot (97%) TKAs and no differences between groups in their final Oxford and Knee Society scores [23].

Several authors have reported favorable outcomes using the medial pivot design with earlier reports of its use [8,24–31]. The pooled survivorship of the medial pivot knee system was exceptionally high, with rates of 99.2% at 5 years and 97.6% at 8 years [32]. Importantly, the medial pivot system demonstrated better survivorship at mid-term follow up compared with unconstrained mobile bearing, posterior-stabilized (PS) mobile bearing, and constrained condylar types, as well as PS fixed bearings at 6 years [32]. These results suggest a potential advantage of the medial pivot design in terms of durability and midterm outcomes compared with several other commonly used insert types. More recently, a systematic review evaluating midterm outcomes of medial pivot found excellent survivorship, low revision rate, and good-to-excellent results in term of PROMs, but failed in reporting high quality study level [11].

The kinematic alignment technique in TKA has demonstrated inherent compatibility with medial pivot knee prosthesis designs since its inception, as both aim to replicate the native knee's function through a highly congruent medial compartment and less-conforming lateral compartment, resulting in enhanced medial pivot motion patterns and appropriate femoral external rotation during flexion [33–39]. A recent randomized controlled trial demonstrated that medial pivot knee prostheses with restricted kinematic alignment yielded superior functional outcomes and higher patient satisfaction at 1 year follow up compared with mechanically aligned implants, with sustained improvements in patient satisfaction and a trend toward better clinical outcome scores over longer-term evaluation [40]. Another matched-cohort study reported higher functional results in kinematically aligned MP TKAs compared with mechanically aligned MP TKA at 1-year postoperative term [41]. Kinematic alignment TKA also demonstrated better tibial internal rotation and femoral rollback during flexion compared with mechanically aligned TKA with MP bearings [38]. Finally, kinematic alignment showed better femoral external rotation during flexion compared with mechanically aligned TKA with MP bearings [39].

Current literature regarding the impact of different medial congruent bearings on clinical outcomes remains limited; however, ball-in-socket medial congruent bearings have demonstrated comparable stability parameters, patient-reported outcomes, and range of motion to intermediate medial congruent bearing designs following unrestricted kinematic alignment [42,43]. According to the 2024 Australian National Registry Report [44], medial pivot designs for primary TKA in osteoarthritis patients demonstrated varying cumulative revision rates at 10 year follow up. The SAIPH (MatOrtho) implant exhibited the lowest cumulative revision rate at 2.9% (95% CI: 2.1–4.1), followed by Evolution (MicroPort) at 4.2% (95% CI: 3.6–5.0), GMK Sphere Primary (Medacta) at 4.3% (95% CI: 3.8–4.9), and MRK (MatOrtho) at 4.7% (95% CI: 3.2–6.8). Analysis by fixation method revealed that cemented fixation (n = 44,123) showed a 10-year cumulative revision rate of 4.3% (95% CI: 3.8–4.7), while hybrid fixation (n = 309) demonstrated a higher but statistically non-significant rate of 6.3% (95% CI: 3.0–13.3; age and gender-adjusted hazard ratio: 1.28, $P = 0.410$). The cementless cohort (n = 35) was insufficiently sized for meaningful long-term comparison. In the author's opinion, cementation technique should be particularly accurate and carefully executed, as the high congruency characteristic of medial pivot designs may be compromised by imperfect cementation over the long term. This concern should remain until additional data, including survivorship outcomes with different alignment techniques, becomes available.

The main limitation of this study was the retrospective design, which inherently carries a risk of selection bias, and the lack of a control group. Additionally, the absence of preoperative clinical scores restricted the ability to fully assess the impact of the surgery on patient outcomes, necessitating reliance on postoperative satisfaction measures for clinical interpretation.

5. Conclusions

The medial pivot knee design demonstrated a high long-term survival rate with low overall revision rates, regardless of the surgical technique used (MR vs. GB) or the postoperative aHKA angles and CPAK phenotypes. The mean survival time for the entire cohort was estimated to be 16.14 years with 97% survival rate and a median follow up of 11.32 years (IQR, 9.57–14.04), with no difference in satisfaction rates between MR and GB techniques although the relative risk showed a trend toward higher failure and dissatisfaction in the MR group without reaching statistical significance.

Ethics

The study adhered to the principles outlined in the Declaration of Helsinki. The Local Ethics Committees reviewed the study protocol and determined that no ethical approval was required, given the purely retrospective and observational nature of the design.

CRediT authorship contribution statement

Matteo Innocenti: Writing – review & editing, Methodology, Conceptualization. **Filippo Leggieri:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation. **Alessandro Civinini:** Resources, Data curation. **Fernando Nahuel Martín Cocilova:** Methodology, Data curation. **Davide Stimolo:** Resources, Data curation. **Roberto Civinini:** Writing – review & editing, Validation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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