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Review

Long-Term Follow-Up of Medial Pivot Total Knee Arthroplasty: A Systematic Review of the Current Evidence

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Abstract: Total knee arthroplasty (TKA) is a popular treatment for end-stage knee osteoarthritis. Advances in understanding knee biomechanics have led to the development of medial pivot (MP) prostheses, which aim to replicate natural knee kinematics. While short- and mid-term studies have shown favorable outcomes for MP-TKA, long-term follow-up studies are limited. This systematic review aims to analyze the available evidence on long-term outcomes of MP-TKA, including survivorship, complications, and patient-reported outcome measures (PROMs). A comprehensive search was conducted in PubMed, Embase, and Cochrane Database of Systematic Reviews for English language studies reporting long-term outcomes of primary MP-TKA. Nine studies with an average follow-up of 12.4 years were included. Data on survivorship, complications, and PROMs were collected and analyzed. The overall survivorship of MP-TKA was 98.2% at an average follow-up of 12.4 years. Aseptic loosening and periprosthetic joint infection (PJI) were the most common reasons for revision, with a revision rate of 0.4% for each. The overall complication rate was 6.6%, with secondary anterior knee pain and PJI being the most frequent complications. The reoperation rate was 3.1%, primarily due to PJI and knee instability. PROMs significantly improved postoperatively. MP-TKA demonstrates favorable long-term outcomes with high survivorship, low complication rates, and enhanced PROMs. The procedure provides reliable management for end-stage osteoarthritis, offering patients improved knee function and pain relief. Further research with standardized reporting and larger sample sizes is needed to validate and compare these findings to other implant designs.

Keywords: total knee arthroplasty; medial pivot; long-term; follow-up; systematic review; knee kinematics

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Citation: Cacciola, G.; Giustra, F.; Bosco, F.; Sabatini, L.; Risitano, S.; De Meo, F.; Braconi, L.; Cavaliere, P.; Massè, A.; Solarino, G. Long-Term Follow-Up of Medial Pivot Total Knee Arthroplasty: A Systematic Review of the Current Evidence. *Prosthesis* **2023**, *5*, 622–634. https://doi.org/10.3390/prosthesis5030044

Academic Editor: Marco Cicciu

Received: 19 June 2023
Revised: 6 July 2023
Accepted: 10 July 2023
Published: 12 July 2023

1. Introduction

Total knee arthroplasty (TKA) is a widely accepted and effective treatment for end-stage knee osteoarthritis. Over the past two decades, there has been a significant increase in the number of primary TKA procedures performed in the United States [1]. The demand for primary TKA surgeries has seen a substantial rise, with a 291% increase from 2005 to 2020, from 471,088 to 1.37 million procedures, and it is projected to reach 3.48 million annually by 2030 [1,2]. Interestingly, the average age of TKA patients has been decreasing while their postoperative expectations regarding functional outcomes and improved quality of life have been increasing [3,4].

Advancements in understanding knee biomechanics have led to the evolution of TKA design [5]. The traditional "four-bar link" model, which portrays knee kinematics as a uniform rollback of the femur on the tibia during flexion, is not sufficient [6,7]. In vivo analyses have demonstrated that during knee flexion, the external femoral condyle not only slides but also rotates around the center of the medial side. In contrast, the medial compartment remains relatively stable, resembling a medial pivot (MP) motion, similar to a ball and socket joint [7]. MP prostheses have been designed to replicate this natural knee kinematics, providing increased conformity on the medial compartment and reduced congruence on the lateral side. This design aims to minimize the risk of condylar liftoff while ensuring anteroposterior (AP) stability through an elevated anterior lip of the polyethylene insert [8–10]. Therefore, recent studies [4,6,7] have provided evidence that the "four-bar link" model in the study of knee kinematics should be reevaluated in light of kinematic analyses performed in vivo that have contributed to the continuous improvement in surgical outcomes and patient satisfaction after MP-TKA surgery [4,6,7,11].

Several studies have reported favorable short- and mid-term outcomes of MP-TKA, including high implant survivorship and patient satisfaction rates [11–13]. One of the potential advantages of MP-TKA is the restoration of "natural knee kinematics", which is expected to improve patients' perception of a more natural knee compared to other implant designs. However, some studies have not shown statistically significant improvements in conventional clinical scores [4,14,15]. Nevertheless, comparative studies using innovative evaluation scores such as the Forgotten Joint Score (FJS) have indicated better functionality in MP-TKA than other implants [16,17].

Despite the growing body of evidence supporting MP-TKA, long-term follow-up studies are scarce, and no systematic reviews (SRs) have been conducted on this topic. This SR aims to analyze the literature on long-term outcomes with an average follow-up period of more than eight years, focusing on patients who underwent primary TKA using an MP prosthesis design. Specifically, we aim to assess (1) the overall survivorship of MP-TKA, (2) the incidence of complications and causes of reoperation, and (3) the patient-reported outcome measure scores (PROMs).

2. Materials and Methods

2.1. Search Strategy and Selection Criteria

This SR followed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines [18–20]. We analyzed the Pubmed, Embase, and Cochrane Database of Systematic Reviews to identify relevant studies about the long-term outcomes of primary MP-TKA. The search encompassed all English language studies available up until May 2023. Keywords such as "total knee arthroplasty", "total knee replacement", "TKR", "TKA", "medial pivot", "MP", "long-term", "outcomes", and "follow-up" were used in combination with Boolean operators "AND" and "OR". Further, the reference lists of included studies were manually reviewed to detect any additional pertinent articles.

2.2. Inclusion and Exclusion Criteria

The identified studies were consolidated in EndNote X7 (Thomson Reuters Corporation, Toronto, Ontario, Canada) for further management. Duplicate papers were located and eliminated. Two authors (GC and LB) independently assessed the titles and abstracts of the remaining articles to determine their relevance to long-term follow-up outcome studies on primary MP-TKA. The inclusion criteria mandated that studies have a minimum average follow-up period of eight years and report the complication rate and reasons for reoperation. Studies with a sample size of fewer than ten patients, follow-up periods shorter than eight years, or non-English language articles were excluded from the analysis. In instances of disagreement over the inclusion or exclusion of an article, a resolution was sought via consultation with the senior author (GS). Initially, 667 records were identified through the database search. After removing duplicates and applying the inclusion and exclusion criteria, nine studies were ultimately selected for qualitative analysis [21–29] (Figure 1).

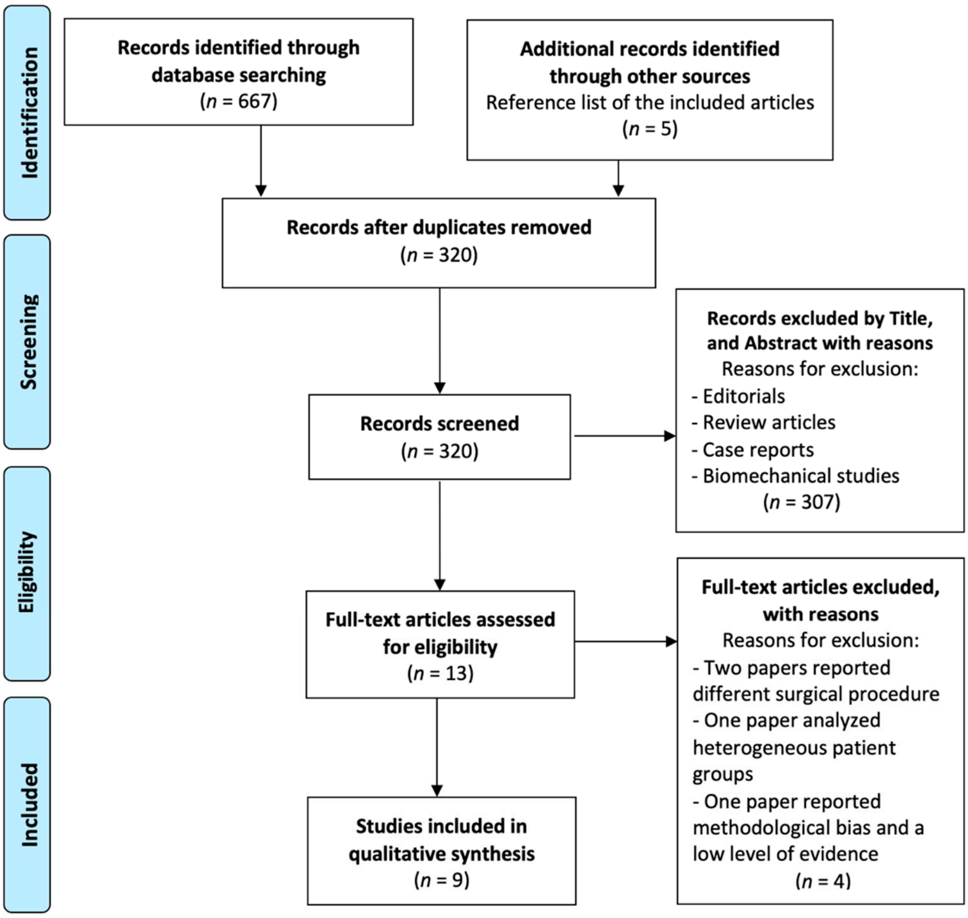

Figure 1. Preferred Reporting Items for Systematic re- views and Meta-Analyses (PRISMA) Flow Diagram.

2.3. Data Collection and Extraction

Two authors (GC and LB) carried out data collection and extraction independently utilizing an Excel Worksheet (Microsoft Office). Any discrepancies were resolved by consulting the senior author (GS) until a consensus was reached. The extracted data encompassed study characteristics (study design and level of evidence), demographic information (number of patients, number of knees, patients lost to follow-up or deceased, average age at the time of surgery), clinical data (diagnosis, implant brand), and outcomes (survival rate, complication rate, reasons for reoperation and complications, and Patient Reported Outcome Measures-PROMs). This information was gathered from the studies included in the analysis.

2.4. Primary and Secondary Outcomes

The primary objective of this SR was to assess the overall survivorship of MP-TKAs and the reasons for implant revision. A "failed" prosthesis was defined as requiring a partial or complete revision of the femoral or tibial component. Secondary objectives included collecting data on all complications and reasons for reoperations. Additionally, PROMs were collected, and average preoperative and postoperative scores were compared as indicators of functional outcomes.

2.5. Assessment of Study Quality

The quality of the included studies was evaluated using the Methodological Index for Non-Randomized Studies (MINORS) criteria scale [30,31]. Commonly utilized in the literature for assessing the quality of non-randomized surgical research, particularly in SRs on knee arthroplasty studies, the MINORS criteria scale includes eight questions, each scored from 0 to 2. A score of 0 indicates that a specific item was not addressed in the study, 1 indicates partial detailing, and 2 indicates complete documentation. Based on the MINORS criteria scale, a study's quality was classified as "good" if it scored 11 to 16 points, "moderate" if it received 6 to 10 points, and "poor" if it scored less than 6 points. The overall quality of the included studies was deemed "good", with an average MINORS score of 9.9 (ranging from 9 to 11). Except for one study that achieved an excellent score [29], all other studies were rated as "good" [21–28].

2.6. Statistical Analysis

Statistical analyses were performed using R software, version 4.1.3 (2022, R Core Team). Categorical variables were analyzed using frequencies and percentages, while continuous variables were summarized using mean, median, and standard deviation (SD). A *p*-value of 0.05 or less was considered to denote statistical significance.

3. Results

3.1. Demographics, Survivorship, and Reasons for Revision

The final analysis comprised nine studies [21–29], encompassing an initial cohort of 2009 MP-TKA procedures. After excluding patients who had died (196 knees, 9.8%) or were lost to follow-up (221 knees, 11%), 1592 patients were included in the final analysis.

Table 1 presents demographic data and the mean length of follow-up. The average age at the time of surgery was 71.3 years, ranging from 63.2 to 78 years. Among the included patients, 443 (27.5%) were male, and 1166 (72.5%) were female. The average follow-up length was 12.4 years, from 8.6 to 15.2 years.

Table 1. Summary of Design and Demographic data.

Authors (Year of Publication)	Study Design (LoE)	N of Knees Initial/Final	N of Knee Died/Lost to Follow-Up	Male/Female Ratio	Mean Age at the Time of Surgery; (Years Old)	Mean Follow-Up (Years)
		N/N	N/N	N/N	Mean ± SD (Range)	Mean ± SD (Range)
Brinkman et al. (2013) [21]	Prospective (III)	50/45	5/0	35/15	69 (45 to 82)	9.96 (1.7 to 14)
Nakamura et al. (2016) [22]	Retrospective (IV)	107/70	23/14	5/102	72 (45 to 85)	11.1 (19 to 13)
Karachalios et al. (2016) [23]	Retrospective (IV)	284/251	20/10	41/184	71 (52 to 84)	13.4 (11 to 15)
Kim et al. (2016) [24]	Prospective (IV)	195/182	5/8	52/130	65.6 (55 to 79)	11 (11 to 12.6)
Macheras et al. (2017) [25]	Retrospective (IV)	385/347	11/14	125/225	78 (58 to 86)	15.2 (15 to 17)
Dehl et al. (2017) [26]	Retrospective (IV)	74/50	9/15	13/35	66.8 (38 to 83)	9.5 (7.7 to 11)
Karachalios et al. (2018) [27]	Prospective (III)	54/54	0/0	18/36	63.2 (52 to 70)	8.6 (8 to 9)
Jenny et al. (2020) [28]	Retrospective (IV)	577/336	109/132	138/198	70.1 ± 7.2	13 (10 to 15)
Ueyama et al. (2020) [29]	Retrospective (IV)	283/257	14/12	16/241	76.2 ± 7.3	10.1 ± 1.7
Overall		2009/1592	192/221	27.5%/72.5%	71.9	12.6

LoE: level of evidence; N: number of evaluation cases; SD: standard deviation.

Table 2 provides information on the surgical procedure design, including decisions regarding the retention or sacrifice of the PCL and the choice to perform patella resurfacing. Seven studies reported whether the posterior cruciate ligament (PCL) was retained or sacrificed [21–26,29]. The PCL was retained in 439 cases (33.4%), while in 876 cases (66.6%), it was sacrificed. Four studies chose to sacrifice the PCL in all cases [22,24,26,29], whereas three studies [21,23,25] made the decision intraoperatively based on the presence of flexion contracture. Eight studies provided information on whether the patella was replaced [21–27,29]. The patella was replaced during the procedure in 628 cases (49.5%).

Table 2. Summary of surgical procedures performed.

Authors (Year of Publication)	MP-TKA Design Used	PCL Retained/ Sacrificed	Patella Resurfacing/ Not Resurfacing
		N/N	N/N
Brinkman et al. (2013) [21]	Advance MP (MicroPort)	27/23	42/8
Nakamura et al. (2016) [22]	MPK (Kyocera Corporation)	0/107	107/0
Karachalios et al. (2016) [23]	Advance MP (MicroPort)	207/77	0/284
Kim et al. (2016) [24]	Advance MP (MicroPort)	0/182	182/0
Macheras et al. (2017) [25]	Advance MP (MicroPort)	205/180	0/285
Dehl et al. (2017) [26]	Advance MP (MicroPort)	0/50	40/10
Karachalios et al. (2018) [27]	Advance MP (MicroPort)	NS	0/54
Jenny et al. (2020) [28]	Aesculap MP (B.Braun)	NS	NS
Ueyama et al. (2020) [29]	Advance MP (MicroPort)	0/257	257/0
Overall		33.4%/66.6%	49.5%/50.5%

PCL: posterior cruciate ligament; MP: medial pivot; TKA: total knee arthroplasty; NS: not specified.

The overall survivorship of MP-TKA, considering any component or patellar resurfacing revision due to anterior knee pain as a failure, was 98.2% at an average follow-up of 12.4 years (8.6 to 15.2).

3.2. Complications, Reoperations and Revisions

The overall complication rate reported in this SR was 6.6% (105 cases) (Table 3). The most frequent complication was secondary anterior knee pain (18 cases, 1.1%), followed by PJI (13 cases, 0.8%), knee arthrofibrosis (12 cases, 0.7%), knee instability (9 cases, 0.6%), periprosthetic fracture (8 cases, 0.5%), aseptic loosening (7 cases, 0.4%), deep vein thrombosis and pulmonary embolism (7 cases, 0.4%), wound dehiscence, component malalignment, patellar fracture, and polyethylene insert wear (1 case each, 0.06%). The overall reoperation rate reported in this SR was 3.1% (49 cases). The most frequent cause of reoperation was PJI (13 cases, 0.8%), followed by knee instability (9 cases, 0.6%), aseptic loosening (7 cases, 0.4%), patellar resurfacing due to secondary anterior knee pain (5 cases, 0.3%), knee arthrofibrosis (2 cases, 0.1%), wound dehiscence, component malalignment, patellar fracture, and polyethylene insert wear (1 case each, 0.06%). The overall revision rate reported was 1.8% (29 cases), and the two most common causes of revision were aseptic loosening (7 cases, 0.4%) and periprosthetic joint infection (PJI) (7 cases, 0.4%). Other reasons for revision included secondary patellar resurfacing for anterior knee pain (5 cases, 0.3%), periprosthetic fracture (4 cases, 0.3%), knee instability (4 cases, 0.3%), component malalignment (1 case, 0.06%), polyethylene insert wear (1 case, 0.06%), and knee arthrofibrosis (1 case, 0.06%).

Table 3. Summary of complications/reoperations/revisions data.

Authors (Year of Publication)	N of Knees	AL	PPF	PJI	KI	AKP	PF	AF	CM	IW	DVP/PE	Wound Dehiscence or Postoperative Effusion	Overall Complications	Overall Reoperations	Overall Revisions
	N	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Brinkman et al. (2013) [21]	45	0 (0%)	**1** (2.2%)	1 (2.2%)	0 (0%)	0 (0%)	1 (2.2%)	7 (15.6%)	0 (0%)	0 (0%)	2/0 (4.4%)	0 (0%)	12 (26.7%)	3 (6.7%)	1 (2.2%)
Nakamura et al. (2016) [22]	70	0 (0%)	**1** + 1 (2.9%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0/0 (0%)	1 (1.4%)	3 (17.1%)	3 (4.3%)	1 (1.4%)
Karachalios et al. (2016) [23]	251	**3** (1.2%)	0 (0%)	**2** (0.8%)	**1** (0.4%)	**2** + 10 (4.8%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0/0 (0%)	0 (0%)	18 (4.8%)	8 (3.2%)	8 (3.2%)
Kim et al. (2016) [24]	182	0 (0%)	0 (0%)	**2** + 5 (3.8%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0/0 (0%)	17 (9.3%)	24 (6.6%)	7 (3.8%)	2 (1.1%)
Macheras et al. (2017) [25]	347	0 (0%)	**1** (0.3%)	0 (0%)	0 (0%)	**3** (0.9%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2/2 (1.2%)	7 (2%)	15 (3.5%)	4 (1.2%)	4 (1.2%)
Dehl et al. (2017) [26]	50	0 (0%)	1 (2%)	**1** (2%)	0 (0%)	0 (0%)	0 (0%)	**1** (2%)	**1** (2%)	0 (0%)	0/0 (0%)	0 (0%)	4 (25%)	4 (8%)	3 (6%)
Karachalios et al. (2018) [27]	54	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (5.6%)	0 (0%)	1 + 2 (5.6%)	0 (0%)	0 (0%)	0/1 (1.9%)	2 (3.7%)	9 (22.2%)	0 (0%)	0 (0%)
Jenny et al. (2020) [28]	336	**4** (1.2%)	0 (0%)	0 (0%)	**2** + 2 (1.2%)	0 (0%)	0 (0%)	1 (0.3%)	0 (0%)	**1** (0.3%)	0/0 (0%)	0 (0%)	10 (3.6%)	10 (3%)	7 (2.1%)
Ueyama et al. (2020) [29]	257	0 (0%)	**1** + 2 (1.2%)	**2** (0.8%)	**1** + 3 (1.6%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0/0 (0%)	1 (0.4%)	10 (4.7%)	10 (3.9%)	4 (1.6%)
Overall	1592	**7** (0.4%)	**4** + 4 (0.5%)	**7** + 6 (0.8%)	**4** + 5 (0.6%)	**5** + 13 (1.1%)	1 (0.06%)	**1** + 1 + 10 (0.7%)	**1** (0.06%)	**1** (0.06%)	4/3 (0.4%)	2 + 26 (1.8%)	105 (6.6%)	49 (3.1%)	29 (1.8%)

Bold = Revision, Underlined = Reoperation. N: number of evaluation cases; DVP = deep vein thrombosis; PE = pulmonary embolism; %: percentage; AL: Aseptic Loosening; PPF: Periprosthetic fracture; Periprosthetic joint infection: PJI; KI: Knee Instability; AKP: Anterior Knee Pain; PF: Patellar Fracture; AF: Arthrofibrosis; CM: component malalignment; IW: Insert Wear.

3.3. Causes of Reoperations

Data summarizing the reasons for reoperation are outlined in Table 3.

Aseptic Loosening: The survivorship rate considering aseptic loosening as a failure in this SR was 99.6%. Seven of the nine studies included reported no reoperations or revisions due to aseptic loosening [21,22,24–27,29]. Only two studies highlighted instances of revisions because of aseptic loosening, marking a prevalence rate of 0.4% [23,28]. Karachalios et al. [23] and Jenny et al. [28] registered a revision prevalence due to aseptic loosening of 1.2%, corresponding to 3 out of 251 and 4 out of 335 MP-TKAs, respectively. Karachalios et al. [23] noted that revisions due to aseptic loosening occurred three, five, and nine years after the index arthroplasty. Notably, in two instances, MP-TKAs revisions were conducted on the same patient who was obese (BMI 41 kg/m^2) [23].

PJI: This SR noted a PJI prevalence of 0.8% (13 cases). For PJI treatment, a protocol of Debridement, Antibiotics, and Implant Retention (DAIR) was utilized in six cases (0.4%), while a two-stage revision with an interim spacer was conducted in 7 cases (0.4%). According to Kim et al., all six patients with a postoperative deep infection initially underwent a DAIR procedure. In two of these cases, the DAIR was unsuccessful, necessitating a two-stage revision to manage the infection [24].

Periprosthetic Fracture (PPF): This study reported a PPF prevalence of 0.5% (8 cases). A component revision was required in half of the cases, while an Open Reduction and Internal Fixation (ORIF) using screws and plates was performed in the remaining cases. Three of the four revisions were conducted due to a periprosthetic fracture of the tibial plate [22,25,29], whereas the fracture location in one case was unspecified.

Knee Instability: The prevalence of knee instability associated with MP-TKA was 0.6% (9 cases). For four of these cases, a revision of one or more components was necessary, while in five cases, a liner exchange proved sufficient.

Anterior Knee Pain: Anterior knee pain was the most reported postoperative complication, with an incidence of 1.1% (18 cases). Although it did not necessitate further reoperation in most instances, 5 cases required secondary patellar resurfacing. Notably, anterior knee pain was solely reported in patients who had not undergone patellar resurfacing during the index arthroplasty.

3.4. Patient-Reported Outcome Measures (PROMs)

A summary of the patient-reported outcome measure scores (PROMs) is presented in Table 4.

Table 4. Summary of patient-reported outcome measure scores (PROMs).

PROMs	N of Studies/ Knees	N of Knees	Preoperative	Postoperative	Delta Pre-Postoperative
	N/N	N			
KSS knee score [21–29]	9/1592	1592	32.8	88.1	55.3
KSS function score [21–29]	8/1492	1492	42.6	78.5	35.9
WOMAC [21,23–25,27]	5/870	870	37.2	61.1	23.9
OKS [23,25,27]	3/652	652	23.2	44.5	21.3
ROM knee flexion (°) [21,22,24–26,29]	6/951	951	103.2	117.6	14.4
SF-12 PCS [23,25,27]	3/652	652	25.8	47.1	21.3

PROMs = patient-reported outcome measures; KSS = Knee Society Score; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index; OKS = Oxford Knee Score; ROM = range of motion; ° = degree; PCS = Physical Score.

Knee Society Score (KSS)-Knee Score: Of the nine studies, eight [21–25,27–29] reported the average preoperative and postoperative KSS knee scores. The average preoperative KSS knee score across all nine studies was 32.8, ranging from 14 to 39.7, while the average postoperative KSS knee score was 88.1, with a range of 84 to 98.1 [21–29]. An average increase of 64.3 points was observed from the preoperative to postoperative phase.

KSS-Function Score: The preoperative and postoperative KSS function scores were reported in eight of the nine studies [21–25,27–29], accounting for 1542 knees. The average preoperative KSS function score was 42.6 (41.5 to 50), while the average postoperative KSS function score was 78.5 (68 to 97).

Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC): Five studies [21,23–25,27] provided the average preoperative and postoperative WOMAC scores for 879 knees. The average preoperative WOMAC score was 37.2 (30.7 to 61), while the average postoperative WOMAC score was 61.1 (22 to 79.3). The data revealed an average increase of 23.9 points from the preoperative to postoperative phase.

Oxford Knee Score (OKS): Three studies [23,25,27] reported the preoperative and postoperative OKS for 652 knees. The average preoperative OKS was 423.2 (22 to 25.1), while the average postoperative OKS was 44.5 (44.4 to 44.5).

Range of Motion (ROM) knee flexion: Five of the nine studies reported the average preoperative ROM [22,24–26,29] for 906 knees, while six studies provided the average postoperative ROM [21,22,24–26,29] for 951 knees. The average preoperative ROM was 103.2°, which increased to an average postoperative ROM of 117.6°.

SF-12 Physical Score (PCS): Three studies reported the average preoperative and postoperative SF-12 PCS [23,25,27]. The average preoperative SF-12 PCS was 25.8 (25.2 to 26.6), while the average postoperative SF-12 PCS was 47.1 (46 to 48.5).

4. Discussion

The main finding of this study was the outstanding implant survival and clinical outcomes associated with MP-TKA during long-term follow-up. The patients demonstrated an impressive survivorship rate of 98.2%, with only 0.4% experiencing failure due to aseptic loosening. The most common postoperative complication reported in this SR was PJI, which was found to be unrelated to implant design. We reported a postoperative incidence of anterior knee pain of 1.1%, necessitating reoperation in only 0.3% of cases. Additionally, all observed scores significantly improved between the preoperative and postoperative stages. Finally, patients experienced satisfactory postoperative ROM, with an average of 117.6°.

The present study revealed favorable long-term survivorship of MP-TKA, with an overall survival rate of 98.2% at an average follow-up of 12.4 years (8.6 to 15.2 years). Aseptic loosening and PJI were the most common reasons for revision in our study population, accounting for a small proportion of cases (0.4% each). These results emphasize the effectiveness of the MP implant design in providing durable survivorship over an extended period [21–29,32]. These findings align with previous mid-term publications, which reported survivorship estimates for MP-TKA equal to or higher than the thresholds for follow-ups of 5 (99.2%) and 8 (97.6%) years, respectively [33,34]. Comparable survivorship rates have also been reported in published studies evaluating other types of implants, even among young and active patients [35,36]. When comparing our findings with the existing literature on other implant designs, it is crucial to consider the variability in study methodologies, patient populations, and follow-up durations. However, several studies have reported comparable or superior survivorship rates with MP-TKA compared to alternative implant designs [37,38]. This suggests the MP design may offer long-term implant stability and longevity advantages.

Sartawi et al. conducted a retrospective case series examining patients who underwent third generation cemented TKA with NexGen prostheses (Zimmer Biomet, Warsaw, Indiana, USA) using posterior-stabilized (PS) and cruciate-retaining (CR) components [39]. Both study groups exhibited similar survival rates at the 15-year follow-up: 98% for PS TKAs and 100% for CR TKAs. Similarly, Meftah et al. found an overall survivorship of 98% at a 12-year follow-up for young, active individuals undergoing PS TKA [40]. In this SR, the cumulative revision rate for all studies was 1.88% at an average follow-up of 12.4 years (30 out of 1592 knees). The overall survival rate, including the revision rate, reported in this SR was slightly higher than the corresponding outcome mentioned in the

2022 Australian Orthopaedic Association National Joint Replacement Registry (AOANJR), where the MP-TKA revision rate at a mean follow-up of 15 years was 2.5% (858 out of 33,823 knees) [41].

Possible reasons for the higher revision rate in the AOANJR data may be attributed to the limitations of the registry itself, as it does not provide surgeon-specific information or document the reasons for loosening or lysis. It is plausible that the revised implants in the registry were affected by severe ligamentous malalignment or imbalance. Additionally, the original Advance prosthesis had a problematic tibial insert locking mechanism, which was subsequently modified in 1999. Unfortunately, the Advance Medial Pivot registry data do not distinguish between the two versions of the prosthesis [41].

In our SR, the cumulative revision rate across all included studies was 1.88% at an average follow-up of 12.4 years, involving 30 out of 1592 knees.

As recently demonstrated, aseptic loosening (7 cases, 0.4%) and PJI (7 cases, 0.4%) were the two most common reasons for the revision. These findings align with the 2022 National Joint Report (NJR) of England and the 2022 AOANJR, which identified the following as the top five reasons for revision in all knee replacements: aseptic loosening/lysis, infection, progressive arthritis, pain, and instability [41–45]. Certain publications have hypothesized that the constricted medial compartment could contribute to insert wear or stresses, leading to failure [46,47]. Theoretically, the wide contact area in the medial compartment and reduced contact stresses provided by the medial-pivot design should result in less insert wear [48–50]. Compared to PS or minimally stabilized implants, the cumulative revision rate of 0.4% (seven revisions out of 1592 TKAs) for these causes does not indicate a higher failure rate due to the constraint placed on the medial compartment of the insert. According to the AOANJR, males have a higher risk of revision, primarily related to an increase in the incidence of infection, and patients in obese classes 2 and 3 have a higher rate of revision for infection compared to patients with a standard body mass index (BMI) [41].

The results of this SR on the outcomes of MP-TKA demonstrated favorable PROMs during long-term follow-up. Our study revealed a postoperative KSS knee score of 88.1 (84 to 98.1), which closely aligns with the findings reported by Longo et al. [51] in their SR comparing CR and PS TKA, where they reported an average postoperative KSS knee score of 90.3 for CR and 90.8 for PS. Furthermore, the KSS function score in our study was 78.5 (ranging from 68 to 97), which closely resembled the average scores reported by Longo et al. [51] for CR (76.6) and PS (77.7). These findings are consistent with other studies investigating various designs of TKA, indicating that the outcomes of MP-TKA are comparable to, if not superior to, alternative designs [36–38,48–51]. These results support the effectiveness and viability of MP-TKA as a reliable option for achieving long-term knee function.

Despite PS implants being known to provide a greater postoperative ROM compared to MP implants, our SR revealed another important finding. We reported an average increase in postoperative ROM of 14.4°, with the average ROM improving from 103.2° to 117.4° [52,53]. In the SR by Longo et al. [51], they reported an average postoperative ROM of 115.2° for CR implants and 119.4° for PS implants, demonstrating a significantly better ROM for the PS design. The optimal results reported in this SR depend on the design of the MP prosthesis [43,44]. The MP implant allows for controlled and smooth femur rotation around a fixed MP point during knee flexion. This replication of the natural knee joint's behavior, where the medial condyle acts as the primary pivot point during flexion, contributes to a more physiological movement and potentially a greater ROM [54–56] (Figure 2).

Furthermore, the stability provided by the MP implant contributes to its increased ROM. The congruent medial compartment offers good ligament stability, balancing flexion, and extension. This stability promotes confident and unrestricted movement, ultimately leading to a greater ROM [55,56].

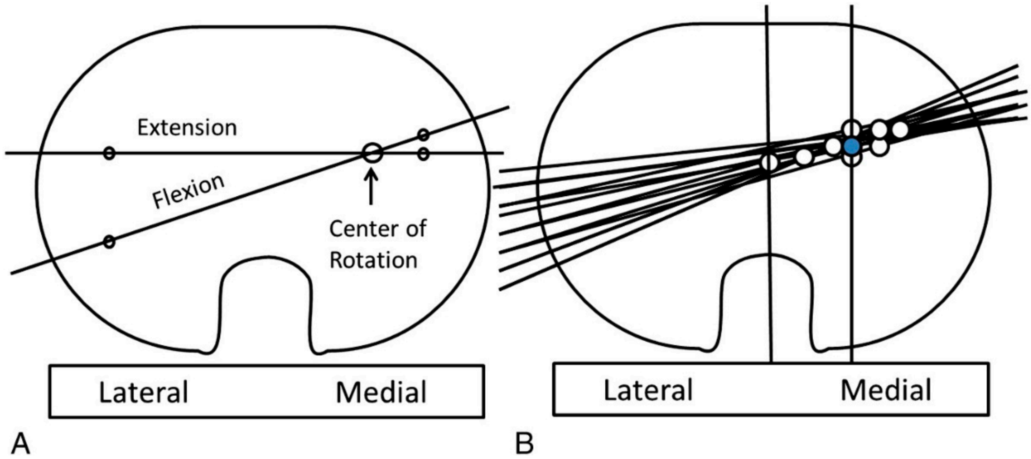

Figure 2. Medial pivot (MP) concept in knee biomechanics. (**A**) The center of axial rotation (white circle) is determined from the projected femoral flexion/extension axis (small circles and lines) over the entire activity. (**B**) Lines representing the projection of the flexion/extension axis are shown. Each white circle represents the computed each center of rotation and blue circle represents the MP point. The figure was reprinted with permission from the study conducted by Nishio Y et al. [45]. The agreement for the reproduction was established between University of Turin–Francesco Bosco and Elsevier (License number: 5583210793526).

The present SR had several limitations that should be acknowledged.

Firstly, the quality and reporting standards of the original studies included in the review exhibited variability, potentially introducing bias, and compromising the reliability of the findings. Furthermore, the included studies employed different inclusion criteria and methodologies for reporting variables, posing data synthesis and comparison challenges. Consequently, the robustness of the synthesized data may be compromised. Second, some of the included studies had relatively small sample sizes of some included studies, which may restrict the generalizability of the results. The findings may not represent broader populations or lack statistical power to detect significant effects. Larger sample sizes are necessary to enhance future investigations' generalizability and statistical validity. Third, another limitation is the potential for publication bias, as the review only considered published studies. This exclusion of unpublished material may have inadvertently missed relevant studies on MP-TKA, introducing a potential bias in the synthesized evidence. Fourth, the functional outcomes assessed in the included studies were evaluated using different scoring systems. This methodological discrepancy introduces variability in the interpretation and comparison of the results. Standardization of outcome measures would enhance the comparability and reliability of future studies. Fifth, it is crucial to account for the influence of surgical techniques employed by various authors, such as the preservation or sacrifice of the PCL and the decision on patellar resurfacing. The variability in surgical approaches across studies may introduce additional sources of heterogeneity, potentially impacting the outcomes under investigation. Future studies could benefit from stratifying analyses based on surgical techniques to understand their influence on outcomes better. Lastly, the insufficient biomechanical, clinical, and outcome data related to varus and valgus knees has impaired the opportunity to compare and evaluate the performance of MP-TKA related to different knee morphotypes.

5. Conclusions

This systematic review investigated the long-term outcomes of patients who underwent MP-TKA implants. The results demonstrated an impressive overall survivorship rate of 98.2% for MP-TKA. The complication rate was 6.6%, with secondary anterior knee pain and PJI emerging as the most frequent complications. The reoperation rate was 3.1%, primarily associated with PJI and knee instability. The revision rate reported was 1.8%, with aseptic loosening and periprosthetic joint infection being the primary reasons for the revision. Moreover, PROMs results indicated a significant improvement in knee function and pain scores following MP-TKA. These findings strongly support that MP-TKA is a reliable long-term treatment option for individuals with end-stage osteoarthritis, offering exceptional survivorship, low complication rates, and notable enhancements in clinical and functional outcomes.

Author Contributions: Conceptualization, G.C. and L.B.; methodology, L.B. and F.B.; software, F.B.; validation, F.B., F.G. and S.R.; formal analysis, L.B.; investigation, G.C.; resources, G.C., F.B. and S.R.; data curation, F.B. and F.G.; writing—original draft preparation, L.B., G.C. and F.B.; writing—review and editing, F.B. and F.G.; visualization, F.G., G.C., L.S., F.D.M. and G.S.; supervision, A.M., P.C. and G.S.; project administration, G.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: All procedures involving human participants' studies followed the institutional and national research committee's ethical standards and the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available in the article.

Conflicts of Interest: The authors declare no conflict of interest.

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