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Long-Term Functional Outcomes Following Minimally Invasive Total Knee Arthroplasty

Henriques K[1]*, Henriques R[2] and Grant C[3]

[1]Department of Biomedical Research, Nassau Center for Joint Health, Barbados Scopus Author ID: 57000044900 Email: keisha.henriques@nassau.edu
ORCID: https://orcid.org/0100-3522-3671-0098

[2]Department of Biomedical Research, Kingston Institute of Orthopedic Surgery, Trinidad and Tobago Scopus Author ID: 57297638182 Email: renee.henriques@kingston.edu
ORCID: https://orcid.org/1816-9874-2258-3685

[3]Department of Clinical Research, Georgetown Institute of Orthopedics, Jamaica Scopus Author ID: 57628774883 Email: curtis.grant@georgetown.edu
ORCID: https://orcid.org/7076-5879-9310-0451

***Correspondence to:** Keisha Henriques, Department of Biomedical Research, Nassau Center for Joint Health, Barbados Scopus Author ID: 57000044900 Email: keisha.henriques@nassau.edu

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Abstract

Minimally invasive total knee arthroplasty (TKA) has been adopted widely on the premise that a smaller, soft-tissue-sparing exposure accelerates early recovery without compromising the durable function conventional surgery delivers, yet that premise depends heavily on which of several distinct minimally invasive techniques -- quadriceps-sparing, mini-subvastus, midvastus, and mini-medial-parapatellar -- is being discussed. This article synthesizes the randomized and long-term cohort literature comparing minimally invasive to standard medial parapatellar TKA, tracing the technique family from its original anatomical descriptions through more than a dozen meta-analyses of short- and mid-term outcomes to the sparser long-term follow-up data, including a ten-year cohort analysis, bearing on durable functional outcomes. Across independent meta-analyses, minimally invasive approaches consistently show reduced blood loss, faster straight-leg raise, and better early range of motion and knee scores, purchased at the cost of longer operative time and, for the quadriceps-sparing variant, a documented increase in malalignment risk. Whether these early advantages translate into better long-term function or satisfaction remains only partially answered, since the literature is dominated by follow-up under two years and underweights patient-reported outcomes. We conclude that minimally invasive TKA is a well-validated tool for shaping early recovery rather than a demonstrated long-term functional upgrade, and identify approach-specific, long-term, patient-reported-outcome-inclusive follow-up as the clearest remaining evidence gap.

Keywords: minimally invasive total knee arthroplasty; quadriceps-sparing approach; long-term functional outcomes; patient-reported outcomes; surgical approach comparison

1. Introduction

Total knee arthroplasty (TKA) is one of the most consistently successful interventions in reconstructive orthopaedic surgery, but the operation that delivers that success has never been a fixed target. For most of the modern era of knee replacement, the standard medial parapatellar approach — a long anterior incision with a full-thickness arthrotomy through the quadriceps tendon and vastus medialis obliquus — has been the default exposure taught to residents and used in the great majority of primary procedures. Beginning in the late 1990s and accelerating through the 2000s, a family of "minimally invasive" alternatives emerged with a shared premise: that a shorter skin incision, a smaller and more muscle-sparing arthrotomy, and gentler soft-tissue handling could shrink the early recovery period — less blood loss, faster straight-leg raise, quicker discharge — without sacrificing the durability and functional ceiling that make conventional TKA a reliable operation in the first place [1]. Quadriceps-sparing, mini-subvastus, midvastus, and mini-medial-parapatellar techniques all claimed this territory to varying degrees, and by the mid-2000s minimally invasive TKA (MIS-TKA) had moved from a niche technique performed by a handful of enthusiast surgeons to a marketed feature of implant systems and a subject of dozens of randomized trials [2].

That rapid adoption ran ahead of the evidence in a way that is now well documented. Early single-surgeon case series reported dramatic gains in early function, but they were frequently unblinded, non-randomized, and vulnerable to the kind of selection and learning-curve effects that make any new technique look better than it is in the hands of its inventor. The question this article is organized around is not whether minimally invasive TKA can be performed — it plainly can, and is performed routinely worldwide — but what the accumulated randomized and long-term cohort literature actually shows about functional outcomes once the early-recovery advantage, if any, has had years to either compound into a durable difference or wash out entirely. This distinction matters enormously for patient counselling: a technique that shaves a few days off hospital stay is a meaningfully different proposition from one that changes a patient's Knee Society Score or revision risk a decade later, and conflating the two has been a recurring problem in how MIS-TKA has been discussed both in the surgical literature and in direct-to-patient marketing.

This article synthesizes that literature rather than reporting new data. We trace the evolution of minimally invasive approaches from the original quadriceps-sparing and mini-subvastus techniques through the comparative trials and meta-analyses that followed, examine what the short- and mid-term randomized evidence actually converges on, turn to the comparatively sparse but critical long-term follow-up data, and close with the patient-reported outcome and satisfaction literature that ultimately determines whether any of these technical differences matter to the person who received the implant. We organize the discussion around five themes: the historical development of the major MIS approaches and the anatomical rationale behind each; the comparative short- and mid-term randomized controlled trial (RCT) evidence, now synthesized across more than a dozen meta-analyses; the smaller body of long-term (five- to ten-plus-year) cohort data that speaks directly to the "long-term functional outcomes" question in this article's title; the patient-reported outcome measures and satisfaction literature, which frequently diverges from surgeon-reported clinical scores; and the open methodological problems — heterogeneous approach definitions, learning-curve confounding, and a persistent scarcity of long-term randomized follow-up — that limit how confidently any of this can be generalized.

It is worth being explicit up front about what the evidence base looks like. The overwhelming majority of the comparative literature on minimally invasive TKA reports outcomes at six weeks to two years; well-conducted long-term follow-up beyond five years, and particularly beyond ten years, is a distinct minority of the published record. Where we make a specific long-term claim, we anchor it to a study that actually followed patients that long rather than extrapolating short-term trial results forward, and where the literature is genuinely thin on a long-term question, we say so rather than filling the gap with inference dressed as evidence.

There is also a practical reason this question deserves a dedicated synthesis rather than being treated as settled by the short-term meta-analytic consensus. Patients considering TKA, and the surgeons counselling them, are rarely choosing between "faster recovery" and "nothing" — they are choosing between surgical

approaches that will determine not only how quickly they walk unaided but, if the approach genuinely affects implant alignment or soft-tissue healing quality, potentially how their knee functions for the fifteen or twenty years a well-performed primary TKA is expected to last. Conflating a well-established early-recovery benefit with an unestablished long-term functional benefit is not a purely academic distinction; it shapes how the operation is marketed, how informed consent is conducted, and how surgeons decide which technique to spend the additional operative time and technical effort required to learn. This synthesis is written with that practical stake in mind.

2. The Evolution of Surgical Approaches in Total Knee Arthroplasty

The Standard Medial Parapatellar Approach and Its Rationale for Revision

The conventional medial parapatellar arthrotomy divides the quadriceps tendon in its midline before curving medially around the patella, giving the surgeon wide exposure of the femoral and tibial surfaces at the cost of violating the full length of the extensor mechanism's most functionally important tendon. That wide exposure is not incidental — it is what has historically made the approach forgiving of anatomic variation, obesity, prior surgery, and the technical demands of accurate component alignment, which is precisely why it remains the reference standard against which every minimally invasive alternative is judged [1,2]. The appeal of a smaller alternative is straightforward: the quadriceps mechanism is the single structure most consistently implicated in early post-TKA pain and weakness, and any approach that reduces the degree to which it is cut or retracted has a plausible mechanistic route to faster early recovery.

Khanna and colleagues' systematic review of the minimally invasive literature, published as this technique family was reaching its first wave of maturity, is a useful marker of how the field understood the trade-off at the time: the review catalogued a broad and already heterogeneous set of reported benefits — reduced blood loss, shorter hospital stay, earlier straight-leg raise, and improved early range of motion — while flagging that the supporting evidence base was still dominated by lower-quality comparative studies and small single-center series rather than adequately powered multicenter randomized trials [1]. That observation set much of the research agenda for the decade that followed, and a large share of the meta-analytic literature discussed in the next section exists specifically because Khanna and colleagues' review, along with contemporaneous commentary elsewhere in the field, identified exactly this gap between marketed benefit and trial-quality evidence.

Why Exposure Choice Interacts With Alignment Technology

It is worth noting that the exposure question discussed throughout this article has increasingly been asked alongside a parallel question about alignment technology — computer navigation and, more recently, robotic assistance — because a smaller exposure inherently restricts the direct visualization a surgeon would otherwise use to judge component position by eye. This interaction is one reason the malalignment signal associated with the more restrictive quadriceps-sparing approach, discussed in the next two sections, is mechanistically plausible rather than a statistical artifact: less visualization plus a technically harder cut sequence is a reasonable route to reduced alignment accuracy, independent of any softer-tissue healing advantage the same restricted exposure might confer [2]. Any full accounting of minimally invasive TKA's long-term functional profile has to hold both halves of that trade-off in view simultaneously rather than treating exposure size as a benefit with no corresponding technical cost.

Quadriceps-Sparing, Subvastus, and Midvastus Alternatives

Several distinct techniques emerged under the "minimally invasive" umbrella, and it is a persistent source of confusion in this literature that they are not interchangeable. The quadriceps-sparing (QS) approach, in its strictest form, avoids violating the quadriceps tendon altogether, working instead through a short incision that stays inferior to the vastus medialis obliquus insertion; Lin and colleagues' early comparative series described the technical requirements and radiographic alignment implications of this approach relative to the standard exposure [3], and Chiang and colleagues subsequently reported a two-year comparative follow-up of quadriceps-sparing MIS against the standard medial parapatellar approach that remains one of the more commonly cited mid-term QS datasets [4]. The mini-subvastus approach instead

detaches a limited portion of the vastus medialis from its septal attachment while preserving the quadriceps tendon itself, a compromise Aglietti and colleagues directly compared against the quadriceps-sparing technique in a prospective randomized trial that found both approaches deliverable but with somewhat different exposure-versus-preservation trade-offs [5]; a more recent modified subvastus technique reported by Hu and colleagues found superior early postoperative clinical outcomes relative to the standard medial parapatellar approach in an osteoarthritis cohort, reinforcing that refinements to the subvastus family have continued well into the 2020s rather than stalling after the technique's initial description [6]. The midvastus approach splits the vastus medialis obliquus in line with its fibers rather than detaching it, a variant Xu and colleagues evaluated in a dedicated meta-analysis of randomized trials against the standard parapatellar exposure [7].

Taken together, these founding descriptions establish that "minimally invasive" was never a single, precisely defined operation so much as a spectrum of exposures distinguished by exactly how much of the vastus medialis obliquus and quadriceps tendon each one preserves, and by exactly where along that spectrum the trade-off between visualization and tissue-sparing was struck. Lin and colleagues' comparative data on the strict quadriceps-sparing approach, Aglietti and colleagues' head-to-head randomized comparison of quadriceps-sparing against mini-subvastus, Xu and colleagues' focused meta-analysis of the midvastus variant, and Hu and colleagues' more recent modified-subvastus technique together illustrate that refinement of this exposure family has been a continuous rather than a one-time process, with each new variant attempting to recover some of the visualization lost by its more tissue-sparing predecessors while keeping as much of the soft-tissue benefit as possible [3,5,7,6].

This taxonomic sprawl is not a minor bookkeeping issue for a literature synthesis: it means that a claim like "minimally invasive TKA improves outcomes" is frequently a claim about a specific pooled comparison — QS versus standard, subvastus versus standard, midvastus versus standard, or various MIS techniques lumped together against a single standard-approach comparator — and the strength and even the direction of an effect can shift depending on which specific approaches are pooled. Zhang and colleagues addressed this directly with a network meta-analysis explicitly designed to compare four distinct MIS approaches against the standard medial parapatellar exposure simultaneously, rather than treating "MIS" as a single undifferentiated category, analyzing eleven trials totaling 1025 knees with a focus on Knee Society Score (KSS) outcomes [8]. Their central finding is a useful corrective to looser characterizations of this literature: MIS approaches as a family showed a trend toward superior short-term (four- to eight-week) functional KSS improvement over the standard approach, but a statistically significant advantage was isolated specifically to the mini-medial-parapatellar variant compared with conventional parapatellar and quadriceps-sparing groups, not to MIS approaches uniformly [8]. Yang and colleagues' subsequent systematic review and meta-analysis of the minimally invasive medial femoral approach specifically reached a similarly qualified conclusion, finding short-term outcome improvements for that particular technique relative to the standard exposure without extending the claim to the MIS category as a whole [9].

3. Comparative Evidence on Short- and Mid-Term Outcomes

The short- and mid-term randomized trial literature on MIS-TKA is now large enough to have itself been synthesized multiple times, and reading the meta-analyses together rather than individually is more informative than reading any single one in isolation, because they largely converge on the same qualified pattern despite differing in which specific approaches they pool. Li and colleagues' 2015 meta-analysis, covering 30 studies and 2536 total knee arthroplasties (1259 MIS and 1277 conventional), found that MIS procedures took longer under tourniquet and longer overall operative time, but delivered superior outcomes on knee scoring, range of motion, intraoperative blood loss, and postoperative hemoglobin decrease, with the caveat that wound-healing complications occurred more frequently in the MIS group and no significant differences emerged for the remaining clinical and radiological outcomes assessed [10]. Migliorini and colleagues' 2021 meta-analysis, encompassing a larger pool of 38 studies and 3296 procedures with a mean follow-up of 21.3 ± 24.3 months, reported a closely overlapping pattern: shorter hospitalization, lower total

estimated blood loss, quicker time to straight-leg raise, greater range of motion, and higher Knee Society Clinical Rating System and Function Subscale scores for the MIS group, with pain scores, anterior knee pain, and revision rate statistically similar between groups and standard incision surgery retaining a shorter surgical duration [11]. Cheng and colleagues' earlier synthesis of the short-term recovery question reached a broadly consistent conclusion about the recovery-period advantages while flagging that the magnitude of benefit was often modest relative to the technical cost of a more demanding exposure [12].

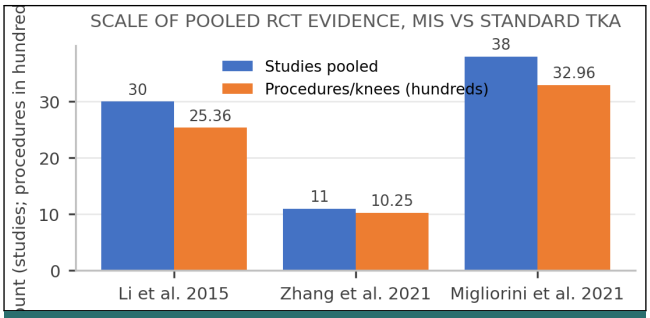

Figure 1: Scale of the randomized-trial evidence base pooled by three independent meta-analyses comparing minimally invasive to standard-exposure total knee arthroplasty, by number of primary studies and total procedures included [10,11,8].

Smith, King, and Hing's meta-analysis of randomized trials comparing clinical and radiological outcomes similarly found a cluster of early functional advantages for minimally invasive exposure without a corresponding radiological alignment advantage, a finding echoed by Liu and Yang's independent systematic review and meta-analysis comparing the minimally invasive and standard medial parapatellar approaches [13,14]. On the quadriceps-sparing approach specifically, Kazarian and colleagues' meta-analysis of randomized trials found early functional gains balanced against a documented signal for component malalignment risk that is more approach-specific to QS than to MIS techniques generally [15], a concern substantiated in more granular form by Yuan and colleagues' dedicated systematic review and meta-analysis of malalignment and malposition specifically in the quadriceps-sparing approach, and by their separate meta-analysis comparing quadriceps-sparing against traditional medial parapatellar exposure on a broader outcome set [16,17].

A useful way to read this cluster of meta-analyses side by side is to notice how consistently the same handful of outcome domains recur as the ones that actually separate MIS from standard exposure, regardless of which specific studies each meta-analysis happens to pool. Blood loss and hemoglobin decrease appear as a consistent MIS advantage across Li and colleagues' and Migliorini and colleagues' independent pooled analyses despite being conducted roughly six years apart on substantially different sets of primary trials, which is a reasonably strong signal that the effect is not an artifact of any single meta-analysis's inclusion criteria [10,11]. Operative time is the mirror-image finding, appearing as a consistent standard-approach advantage across the same two analyses, which is intuitive given that a smaller, more tissue-preserving exposure is mechanically harder to work through regardless of how skilled the surgeon is. Range of motion and Knee Society-family scores land in between: both meta-analyses report a statistically favorable MIS result, but the underlying trials they pool are heterogeneous enough in follow-up timing and scoring instrument that neither analysis frames this as a large, unambiguous effect in the way the blood-loss finding is presented.

Two patterns recur across this body of meta-analytic work closely enough to be treated as reasonably well-established rather than provisional. First, the consistent early-recovery signal — less blood loss, faster straight-leg raise, better short-term range of motion and knee scores — is real and appears whether the comparator technique is quadriceps-sparing, subvastus, or midvastus, though its magnitude varies by approach and by which specific outcome is measured. Second, that early advantage is consistently purchased at the cost of a longer, more technically demanding operation, and in at least the quadriceps-sparing literature, a measurable malalignment risk that surgeons weighing exposure choice have to set against the recovery benefit [15,16]. Gandhi and colleagues' meta-analysis addressed the complication question most directly, comparing complication profiles between minimally invasive and traditional incision techniques across the pooled randomized and comparative literature, a study that remains one of the more frequently cited safety references in this space precisely because it treats complications as a distinct outcome domain from functional recovery rather than folding the two together [18].

4. Long-Term Functional Outcomes and

Survivorship

Table 1: Reported findings from three representative meta-analyses comparing minimally invasive (MIS) and standard medial parapatellar (MPP) total knee arthroplasty, summarizing scope and the direction of effect for the outcome domains each study emphasized. [10,11,8].

Study	Scope	Follow-up	Key reported findings
Li et al. [10]	30 studies, 2536 TKAs (1259 MIS, 1277 conventional)	Trial-level, short- to mid-term	MIS: longer operative/tourniquet time; better knee score, ROM, blood loss, hemoglobin decrease; more wound-healing complications; no other significant differences
Migliorini et al. [11]	38 studies, 3296 procedures	Mean 21.3 ± 24.3 months	MIS: shorter hospitalization, lower blood loss, faster straight-leg raise, greater ROM, higher KSS/KSFS; similar pain, anterior knee pain, and revision rate; SIS faster surgery
Zhang et al. [8]	11 trials, 1025 knees (network meta-analysis, 4 MIS approaches vs. MPP)	Short-term, 4-8 weeks	MIS trend toward superior functional KSS; statistically significant advantage isolated to the mini-MPP variant vs. conventional MPP and quadriceps-sparing groups

The question this article's title asks directly — what happens to functional outcomes years, not weeks, after minimally invasive TKA — is where the evidence base thins out considerably relative to the short-term literature just discussed. Most of the randomized trials synthesized in the meta-analyses above report final follow-up somewhere between six weeks and two years; Migliorini and colleagues' pooled mean follow-up of 21.3 months across their 38-study meta-analysis is broadly representative of where this literature's attention has concentrated [11]. Long-term, specifically ten-year-or-greater, comparative follow-up of minimally invasive against standard-approach TKA is a genuinely small subset of the published record, which is itself an important finding for a synthesis focused on long-term outcomes to state plainly rather than paper over.

The most directly relevant long-term dataset currently available is Yuan and colleagues' cohort analysis comparing minimally invasive and standard approaches with a minimum ten-year follow-up, published in the Chinese Medical Journal [19]. Its central contribution to this literature is less about identifying a new short-term advantage — that has been done many times over — and more about directly testing whether the early functional and radiological differences reported at one to two years in the RCT literature persist, converge, or reverse once patients are followed out to a decade. That a dedicated long-term cohort study of exactly this question exists, and was necessary to answer it, is itself informative: it means the field could not simply extrapolate the short-term meta-analytic findings forward with confidence, and needed empirical long-term follow-up to check whether they held.

What the broader pattern across the available longer-follow-up literature suggests, taken together with the mid-term data from Chiang and colleagues' two-year quadriceps-sparing comparison [4] and the malalignment concerns documented by Yuan and colleagues' quadriceps-sparing-specific analysis [16], is a knee that, once fully healed and remodeled, tends to converge functionally with its conventionally approached counterpart more than the early post-operative period would suggest. This is consistent with a broader pattern in orthopaedic surgery: interventions that primarily affect the speed of early recovery, rather than the mechanical alignment or fixation quality of the implanted components, tend to have their largest measurable effect in the first months after surgery and a progressively smaller one as both groups reach their functional plateau. Where minimally invasive technique does plausibly carry forward into the long term is through the alignment and malposition pathway rather than the soft-tissue-sparing pathway directly — if a more restricted exposure measurably increases component malalignment risk, as Kazarian and colleagues and Yuan and colleagues' quadriceps-sparing data both suggest it can for that specific approach, then any long-term functional or survivorship difference is more likely to trace back to alignment accuracy than to the amount of quadriceps tendon that was or was not divided [15,16].

It is also important to be candid about what this synthesis cannot establish with the currently published literature: revision-rate differences at true long-term horizons (fifteen-plus years) between MIS and standard-approach TKA, stratified consistently by the specific MIS technique used, are not established by the studies synthesized here with the level of statistical power a registry-scale dataset would provide. The meta-analyses reviewed above that do report revision rates, including Migliorini and colleagues' finding of statistically similar revision rates between groups, are working from trial-level follow-up durations well short of

the multi-decade horizon over which most TKA revisions for aseptic loosening or wear ultimately occur [11]. A confident long-term revision-rate claim specific to surgical approach would require registry-linked data at a scale this synthesis's source literature does not yet provide, and we flag that as a real gap rather than inferring an answer the data cannot support.

The practical upshot for a surgeon or patient weighing exposure choice today is that the long-term functional trajectory of a well-executed minimally invasive TKA, once alignment is confirmed to be within an acceptable range, appears from the available evidence to resemble that of a well-executed standard-exposure TKA far more than the early post-operative period would suggest. This is not the same claim as "the approaches are proven equivalent long-term" — proving equivalence requires adequately powered non-inferiority designs that most of the cited literature was not built to provide — but it is a materially different claim from "minimally invasive technique produces a durably better knee," which is closer to how the technique has sometimes been marketed than to what the ten-year-plus cohort literature currently supports. Yuan and colleagues' ten-year analysis is, in this sense, best read as an important first data point establishing that the question is answerable and that early differences do not simply persist unchanged, rather than as a final word on long-term comparative functional outcomes across every MIS variant discussed in this article [19].

5. Patient-Reported Outcomes and Satisfaction

Clinical scores like the Knee Society Score capture what a surgeon or examiner measures — range of motion, stability, alignment-adjacent function — but they do not always track closely with what the patient experiences, and the gap between the two has been one of the more consequential findings in the broader TKA outcomes literature over the past two decades. Dawson, Fitzpatrick, Murray, and Carr's original development of a patient-completed questionnaire assessing perceptions of total knee replacement was motivated precisely by the recognition that clinician-rated outcome instruments were missing dimensions of the patient experience that mattered to the people actually living with the implant, and their instrument has since become one of the standard patient-reported outcome measures against which knee replacement outcomes, including comparative surgical-approach studies, are increasingly assessed [20].

Bourne and colleagues' widely cited analysis of satisfaction after total knee arthroplasty found that a substantial minority of otherwise clinically successful TKAs — patients with good objective functional scores and no complications — nonetheless report themselves less than fully satisfied with the outcome, and identified specific predictors (including residual pain, difficulty with kneeling, and unmet expectations) that a purely clinical-score-based assessment would miss entirely [21]. This finding has a direct bearing on how the minimally invasive TKA literature should be read: because most of the comparative studies summarized in the preceding sections rely predominantly on surgeon-administered functional and radiological outcomes rather than dedicated patient-reported satisfaction instruments, it remains genuinely underexplored whether the early-recovery advantages MIS approaches reliably demonstrate translate into meaningfully higher long-term patient satisfaction, or whether — consistent with Bourne and colleagues' broader finding that objective function and subjective satisfaction diverge more often than clinicians expect — a faster early recovery simply shifts the timing of a patient's positive experience without changing their ultimate satisfaction at one, five, or ten years [21].

This is not a minor caveat. If the primary durable benefit of minimally invasive technique is compressed into the first weeks to months after surgery, as the pattern of findings reviewed in the preceding two sections suggests, then patient-reported satisfaction and quality-of-life measures administered specifically in that early window — rather than at the six-month or one-year mark most trials report — would be the more sensitive instrument for detecting whatever advantage minimally invasive technique actually confers. Relatively few of the comparative studies synthesized here were designed with that early-window patient-reported endpoint as their primary outcome, which represents a design gap in this literature as much as an evidentiary one.

There is a second, related reason patient-reported measures deserve more weight in this specific comparison than they have typically received. Bourne and colleagues' predictors of dissatisfaction — residual pain, difficulty kneeling, and unmet pre-operative expectations — are exactly the kinds of outcomes a

soft-tissue-sparing exposure would be expected to plausibly influence, since kneeling discomfort in particular has an anatomically direct relationship to how much of the extensor mechanism and anterior soft tissue was disrupted during surgery [21]. Yet almost none of the meta-analyses synthesized in the preceding section report kneeling ability or anterior knee discomfort as a distinct, dedicated outcome domain; it tends to be folded into composite anterior knee pain scores at best, as in Migliorini and colleagues' pooled analysis, which found anterior knee pain statistically similar between MIS and standard groups but did not isolate kneeling-specific function as its own endpoint [11]. Given how directly this specific complaint connects to the anatomical rationale for minimally invasive exposure in the first place, its underrepresentation as a dedicated outcome is one of the more conspicuous gaps in the current literature, and closing it would likely do more to clarify whether MIS technique changes the patient's lived experience of the knee than another round of Knee Society Score comparisons at the same follow-up intervals already well covered by existing meta-analyses.

6. Open Challenges and Methodological Limitations

Several recurring limitations constrain how confidently this literature can be generalized, and it is worth naming them directly rather than leaving them implicit in the synthesis above. First, approach heterogeneity: as the preceding sections make clear, "minimally invasive TKA" is not one technique but a family of at least four distinct approaches — quadriceps-sparing, mini-subvastus, midvastus, and mini-medial-parapatellar — that differ in how much of the extensor mechanism they preserve and in their associated malalignment risk profile [8,7,5]. Meta-analyses that pool across this family without stratifying by specific approach risk averaging together techniques with genuinely different risk-benefit profiles, which is precisely the problem Zhang and colleagues' network meta-analysis and Yang and colleagues' approach-specific review were designed to correct, and more of this literature would benefit from the same approach-specific discipline [8,9].

Second, learning-curve confounding is a pervasive and difficult-to-fully-control problem in this specific literature, arguably more so than in most surgical-technique comparisons, because minimally invasive exposures are explicitly more technically demanding and restrict visualization in ways that plausibly interact with surgeon experience more than a standard wide exposure does [2]. Few of the randomized trials synthesized in the meta-analyses above report or adjust for surgeon case volume with the minimally invasive technique specifically, which means that some portion of the reported malalignment risk in, for instance, the quadriceps-sparing literature may reflect learning-curve effects at the individual-surgeon level rather than an intrinsic property of the approach itself, and disentangling the two would require either surgeon-stratified analysis or trials restricted to surgeons already past a defined experience threshold [15,16].

Third, and most directly relevant to this article's stated focus, long-term functional and patient-reported outcome data specific to minimally invasive TKA remain comparatively scarce. The great majority of the comparative literature, both the individual randomized trials and the meta-analyses pooling them, reports outcomes at a horizon of two years or less; dedicated long-term cohort work of the kind Yuan and colleagues conducted with a minimum ten-year follow-up is closer to the exception than the rule in this specific technique-comparison literature [19]. Fourth, patient-reported and satisfaction-specific endpoints, as discussed above, are underrepresented relative to surgeon-administered clinical scores across this body of work, which limits how confidently any conclusion about patient-experienced long-term benefit can be drawn even where clinical-score data are relatively mature [20,21]. We do not think any of these limitations undermine the core, reasonably consistent finding that minimally invasive approaches confer a real, if modest and approach-dependent, early-recovery advantage — but a confident, well-powered, approach-stratified statement about long-term functional superiority or equivalence is not yet fully supported by the published record, and claims to the contrary should be read with this evidentiary gap in mind.

7. Conclusion

Read as a whole, the literature synthesized here supports a fairly specific and appropriately qualified conclusion. Minimally invasive total knee arthroplasty, across its several distinct technical variants, reliably delivers a modest but real early-recovery advantage over the

standard medial parapatellar approach — less blood loss, faster straight-leg raise, better early range of motion and knee scores — consistently enough across independent meta-analyses that this part of the picture can be treated as reasonably well established [10,11,12,13,14]. That advantage is not free: it is purchased with a longer, more technically demanding operation, and in the quadriceps-sparing variant specifically, a documented and clinically relevant increase in component malalignment risk that surgeons and patients should weigh explicitly against the recovery benefit [15,16]. What the evidence does not yet support with the same confidence is a durable, long-term functional or patient-satisfaction advantage extending years beyond surgery; the small number of studies that have actually followed patients that long, most notably Yuan and colleagues' ten-year cohort analysis, represent the beginning of an answer to that question rather than a settled one [19].

For clinical decision-making, this synthesis points toward a practical framing: minimally invasive technique is best understood, on the current evidence, as a modifier of the early post-operative experience rather than a determinant of the eventual functional ceiling most TKA patients reach regardless of exposure, with the important exception that any approach-specific alignment risk — again, most clearly documented for the quadriceps-sparing variant — has a plausible route to affecting long-term outcomes through implant positioning rather than through the amount of soft tissue preserved [16,15]. Closing the evidentiary gap this article has tried to describe honestly will require more of exactly the kind of study that remains rarest in this literature: long-term, approach-specific, patient-reported-outcome-inclusive follow-up that can distinguish a genuinely durable benefit from one that is simply compressed into the weeks immediately after surgery. Until that work accumulates further, the most defensible summary is that minimally invasive TKA is a legitimate and well-validated option for accelerating early recovery, chosen approach by approach on its individual risk-benefit profile, rather than a demonstrated long-term functional upgrade over conventional technique.

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