

Original Research Article

Remote follow-up after total knee arthroplasty: validity of patient-reported outcome measures as a triage tool – a prospective cohort study

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ABSTRACT

Background: Routine in-person review after total knee arthroplasty (TKA) is costly and resource-intensive. Whether remotely-collected patient-reported outcome measures (PROMs) can reproduce the clinician's follow-up decision-not merely correlate with it-is unknown. We assessed the agreement and triage accuracy of three PROMs against the clinician-administered knee society score (KSS), and whether comorbidity should modify follow-up.

Methods: In this prospective cohort of 96 patients undergoing primary TKA for osteoarthritis, the Oxford knee score (OKS), Western Ontario and McMaster universities osteoarthritis index (WOMAC), short form (SF)-36 and KSS were recorded preoperatively, at 3 weeks and at 1 year. Agreement was assessed by Bland-Altman analysis, triage accuracy by ROC analysis against a clinician-defined suboptimal outcome (lowest-quartile 1-year KSS), and predictors by multivariable regression.

Results: Data were complete for all 96 patients (mean age 66.1 years; 72.9% comorbid; no loss to follow-up). All instruments improved by 1 year ($p < 0.001$). Despite high PROM-KSS correlations (1-year OKS $r = 0.96$), Bland-Altman analysis showed systematic disagreement (WOMAC bias +19.9 standardised points), so the instruments are not interchangeable. A remote OKS < 28 identified the suboptimal outcome with area under the curve 0.98, sensitivity 100%, specificity 93%, negative predictive value 100% and kappa 0.88, missing no affected patient. Comorbidity count independently predicted poor outcome (adjusted odds ratio 4.0 per comorbidity, $p < 0.001$); 1-year KSS fell stepwise across strata ($p < 0.001$).

Conclusions: After the 3-week visit, a normal remote OKS reliably excludes a poor clinician-defined outcome, supporting a comorbidity-stratified hybrid pathway: remote follow-up for low-risk patients and in-person review for high-risk patients. External, longer-term validation is required.

Keywords: Total knee arthroplasty, Patient-reported outcome measures, Remote follow-up, Telemedicine, Knee society score, Comorbidity

INTRODUCTION

Knee osteoarthritis is a leading cause of chronic disability worldwide, and TKA reliably relieves pain and restores function in advanced disease.¹ Despite excellent aggregate results, roughly one in five patients remains dissatisfied, usually because of unmet expectations, persistent pain or

an unrecognised complication.²⁻⁴ Detecting that minority early is the central purpose of postoperative surveillance.

Conventional surveillance is anchored to the clinician-administered KSS, which couples an examiner's findings with patient-reported function and has a validated outcome categorisation.^{5,6} It requires repeated clinic attendances—commonly at 6 weeks, 3 months, 6 months and yearly—that

burden patients with travel, lost earnings and out-of-pocket cost while crowding already-stretched arthroplasty services.^{7,8} In a single-surgeon cost study, fewer than one in ten routine visits actually changed management, yet each added substantial cost to patient and system alike.⁸ These pressures are greatest in high-volume, resource-constrained settings, where the case for remote follow-up is correspondingly strongest.^{7,9}

Telemedicine after joint replacement reduces unscheduled visits and preserves satisfaction, and PROMs such as the OKS, the WOMAC and the SF-36 are attractive remote instruments because they are brief, self-administered and have established minimal clinically important differences.⁹⁻¹² Their routine use for surveillance nonetheless remains contested: critics note that a questionnaire cannot, by itself, detect a radiographically silent problem such as early loosening or infection.¹²

Most prior work has stopped at reporting how strongly a PROM correlates with a clinician score. This is the wrong question for three reasons.

First, the modern KSS itself incorporates patient-reported items, so a high PROM-KSS correlation is partly expected and tells us little.^{5,6}

Second, a high correlation coefficient does not establish agreement: two instruments can move together yet differ by a clinically important, systematic amount—a distinction correlation cannot reveal but Bland-Altman analysis can.¹³ Third, what a remote pathway actually needs is not a correlation but a reliable decision: can a questionnaire completed at home reproduce the triage choice the surgeon would have made in clinic, and in particular never miss the patient who needs to be seen? Finally, almost all validation data derive from high-income Western registries, leaving the high-comorbidity South Asian populations—who would benefit most from remote follow-up—largely unstudied.

We therefore reframed the problem around clinical decision-making and set four aims to quantify the agreement (not merely the correlation) between each PROM and the KSS using Bland-Altman analysis; to determine the triage accuracy and decision-concordance of remotely-collected PROMs for identifying a clinician-defined suboptimal outcome, using ROC analysis and Cohen's kappa; to test whether comorbidity burden independently predicts outcome and should therefore modify follow-up intensity; and to integrate these findings into a stage-specific, comorbidity-stratified remote triage pathway.

The OKS, WOMAC and SF-36 were chosen deliberately to span joint-specific pain, joint-specific function and general health-related quality of life while remaining short enough for repeated home completion; the 42-item Knee injury and Osteoarthritis Outcome Score was judged too burdensome for serial remote use, and the Forgotten Joint

Score (FJS), which gauges joint awareness, was considered peripheral to triage.

METHODS

This prospective cohort study was conducted at a tertiary-care teaching hospital in western India between July 2022 and June 2024 and is reported in accordance with the STROBE statement for observational studies.¹⁵ The study was approved by the Institutional Ethics Committee of the institution (IEC approval No: IEC/ORTHO/04/2022), and written informed consent was obtained from every participant. All procedures conformed to the Declaration of Helsinki.

Consecutive patients aged ≥ 40 years undergoing primary TKA for primary knee osteoarthritis were eligible. The indication for surgery was symptomatic, radiographically confirmed osteoarthritis (Kellgren-Lawrence grade III-IV) that had failed at least six months of structured non-operative treatment. Exclusion criteria were revision or simultaneous bilateral surgery, inflammatory arthritis, severe cognitive impairment precluding reliable self-report, uncontrolled systemic disease (for example diabetes with HbA1c $> 8\%$), and inability to access or complete electronic forms. All arthroplasties were performed by consultant arthroplasty surgeons using a standard medial parapatellar approach and a cemented implant.

The KSS served as the in-clinic reference standard and was administered by an orthopaedic surgeon during physical examination. The three PROMs were the OKS (12 items; pain and function subscales), the WOMAC (pain, stiffness and physical-function subscales) and the SF-36 (bodily pain and physical-functioning domains). To allow direct comparison and Bland-Altman analysis, every total score was oriented so that higher values denote a better state and was linearly standardised to a 0-100 scale; subscale values are reported on their native scales.

Assessments were made preoperatively (at admission), at 3 weeks (suture removal—the final scheduled in-person visit and the point at which the remote pathway would begin) and at 1 year. The 3-week assessment was deliberately positioned as the hand-over to remote follow-up after wound review rather than as a measure of final function, which it is not. PROMs were completed by patients themselves on a secure electronic form (Google Forms), reproducing the conditions of genuinely remote data capture; the KSS was recorded independently by a surgeon who was blinded to the patient's PROM responses, to avoid information bias. No financial or other incentive was offered for completion.

Comorbidities were abstracted from the medical record, counted, and classified in two complementary ways informed by the Charlson framework:²² by number (0, 1-2 or ≥ 3 conditions) and by severity (none; metabolic-only, for example-controlled hypertension, diabetes or

hypothyroidism; or major-organ disease, for example cardiac, chronic respiratory, chronic kidney, cerebrovascular or chronic liver disease). This addresses the limitation of simple binary stratification by distinguishing the well-controlled metabolic patient from the patient with end-organ disease.

For a diagnostic-accuracy aim, detecting an area under the ROC curve of 0.80 against the null value of 0.5, with 80% power, a two-sided alpha of 0.05 and an anticipated event fraction of approximately 25%, requires of the order of 50-60 participants.²⁶ We enrolled 96 consecutive eligible patients, which exceeds this requirement and yields a precision (95% confidence-interval half-width) below 0.04 for the primary accuracy estimate.

Distributions were examined before analysis. Within-patient change from baseline to 1 year was tested with the Wilcoxon signed-rank test, and responsiveness was summarised as the standardised effect size (mean change divided by the baseline standard deviation) with bootstrap confidence intervals. Concurrent association between each PROM and the KSS was quantified with Pearson and Spearman coefficients and 95% confidence intervals, interpreted cautiously given the shared construct. Agreement was assessed by Bland-Altman analysis on the standardised scores, reporting bias and 95% limits of agreement.¹³

For triage, a suboptimal 1-year outcome was pre-specified as the lowest quartile of the clinician-administered KSS; each PROM's ability to identify this state was evaluated by ROC analysis, with an optimal cut-off chosen by the Youden index and reported with sensitivity, specificity, predictive values and Cohen's kappa for decision-concordance.²⁵

Independent predictors were examined with multivariable linear regression (1-year KSS) and logistic regression (suboptimal outcome) adjusting for age, sex, comorbidity count and baseline score, and the comorbidity gradient was tested with the Kruskal-Wallis test. Complete data were available for all participants, so no imputation was required. Analyses used Python 3.11 (SciPy, statsmodels and scikit-learn); a two-sided $p < 0.05$ was considered significant.

RESULTS

Ninety-six patients were enrolled and all completed every assessment at baseline, 3 weeks and 1 year, with no loss to follow-up and no missing items (Figure 1). The mean age was 66.1 years (SD 7.5; range 45-82) and the sexes were evenly represented (49 men, 47 women).

Comorbidity was common (72.9%): hypertension in 54%, diabetes in 34% and a chronic respiratory condition in 15%, with smaller numbers of cardiac, renal and cerebrovascular disease. By count, 26 patients had no comorbidity, 54 had one or two and 16 had three or more;

by severity, 26 had none, 56 had metabolic-only disease and 14 had major-organ disease.

Every instrument improved significantly from baseline to 1 year (Wilcoxon $p < 0.001$ throughout), with large effect sizes—for example KSS pain 2.89, OKS total 1.62 and WOMAC total 1.61 (Table 1). Pain gains were largely realised by 3 weeks, whereas functional scores continued to rise out to 1 year, mirroring the expected trajectory of recovery after TKA.

Cross-sectional correlations between the PROMs and the KSS were high at every timepoint (preoperative OKS $r = 0.995$; 1-year OKS $r = 0.96$, WOMAC $r = 0.93$; Spearman coefficients were comparable), reproducing-and contextualising-the strong correlations previously reported (Figure 2). Agreement told a more nuanced story. Bland-Altman analysis at 1 year showed a systematic offset between each PROM and the KSS: WOMAC over-estimated standardised knee status by +19.9 points (limits of agreement +1.5 to +38.4), SF-36 by +12.4 (-1.3 to +26.0) and OKS by +11.1 (-2.6 to +24.8) (Figure 3). The OKS showed the smallest, most consistent bias. In other words, the PROMs track the KSS closely but are not numerically interchangeable with it—precisely the distinction that a correlation coefficient conceals.¹³

Twenty-six patients (27%) met the pre-specified clinician-defined threshold for a suboptimal 1-year result (lowest-quartile KSS). Treated as a remote triage test, the patient-completed OKS identified these patients with an area under the curve of 0.98 (95% CI 0.96-1.00); an OKS total below 28 gave a sensitivity of 100%, specificity of 93%, negative predictive value of 100% and kappa of 0.88, and critically misclassified none of the affected patients as well (zero false-negatives). WOMAC (AUC 0.98, kappa 0.85) and SF-36 (AUC 0.98, kappa 0.77) performed similarly but with lower specificity and more false-positive referrals (Table 2). The 100% negative predictive value is the operationally important figure: a normal remote OKS reliably excludes the clinician-defined poor outcome and so safely defers an in-person visit.

On multivariable logistic regression, comorbidity count was a strong independent predictor of a suboptimal outcome (adjusted odds ratio 4.0 per additional comorbidity, 95% CI 1.8-9.0, $p < 0.001$), as was older age (odds ratio 1.21 per year, 95% CI 1.04-1.40, $p = 0.013$); sex was not associated (Table 3).

One-year knee outcome fell stepwise as comorbidity burden rose—mean KSS 215.6 with no comorbidity, 168.0 with one or two and 124.6 with three or more ($p < 0.001$)—and declined in parallel with comorbidity severity (none 215.6, metabolic-only 165.3, major-organ 129.2) (Figure 4). Baseline score was the dominant determinant of the 1-year score in the linear model ($p < 0.001$), consistent with the principle that a patient's starting state largely sets their endpoint.

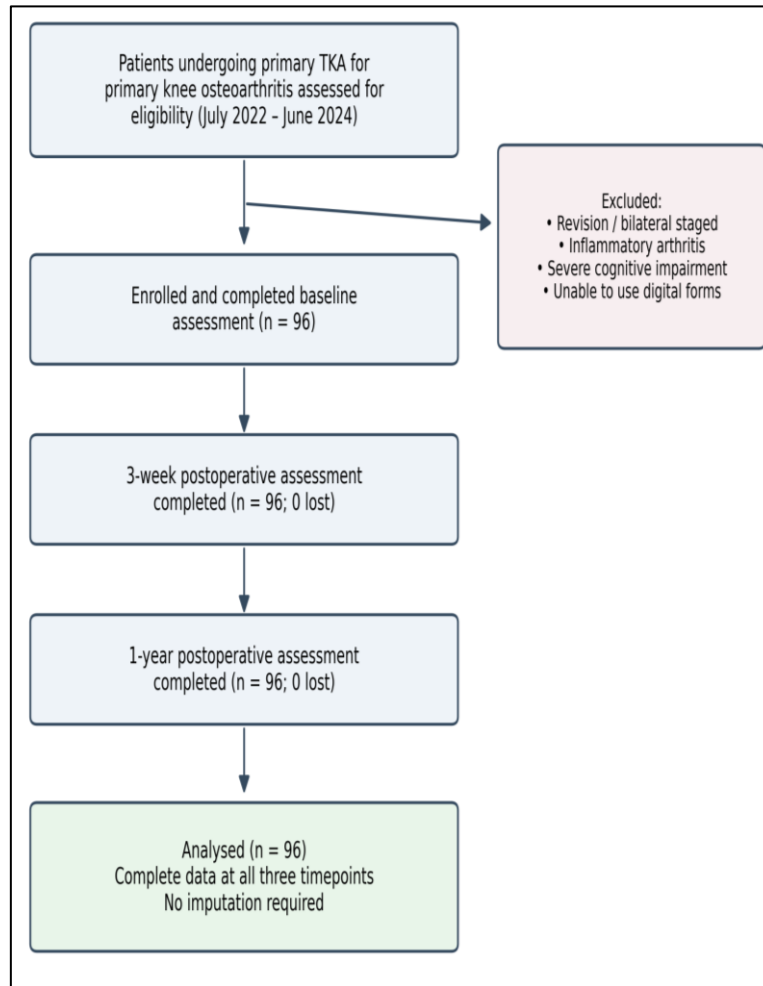


Figure 1: Participant flow.

*All 96 enrolled patients completed every assessment with no loss to follow-up, so no imputation was required.

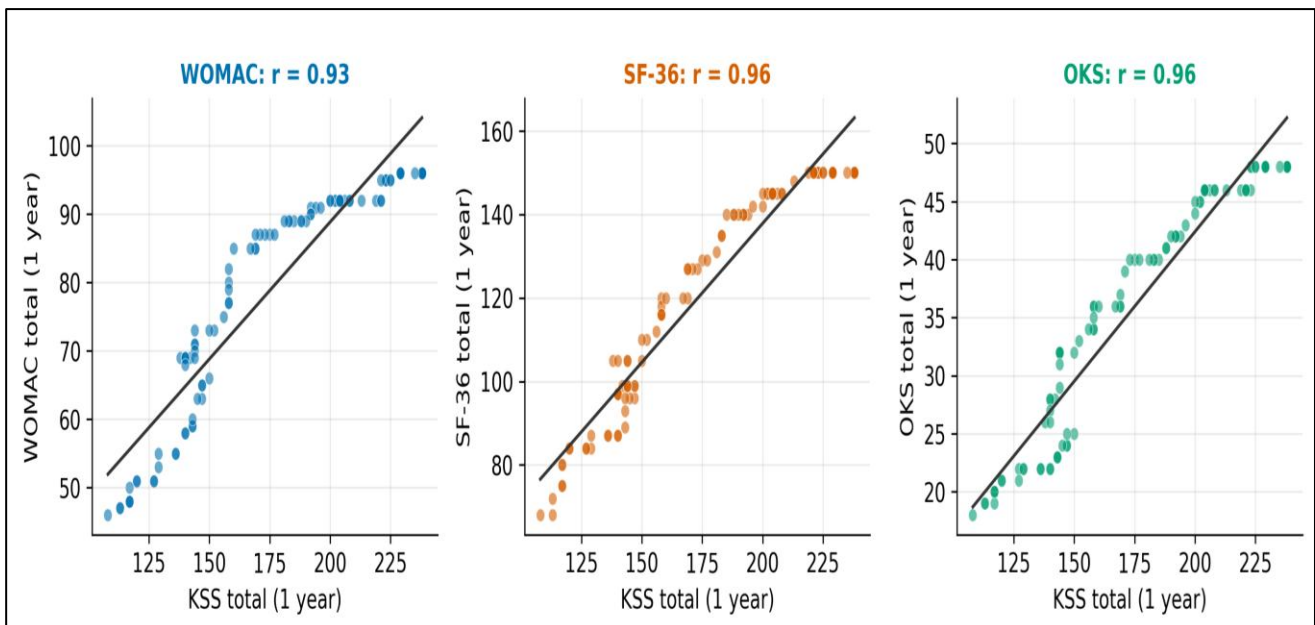


Figure 2: Concurrent association between the KSS and each PROM at 1 year (Pearson r shown).

*Strong correlation does not, by itself, establish agreement.

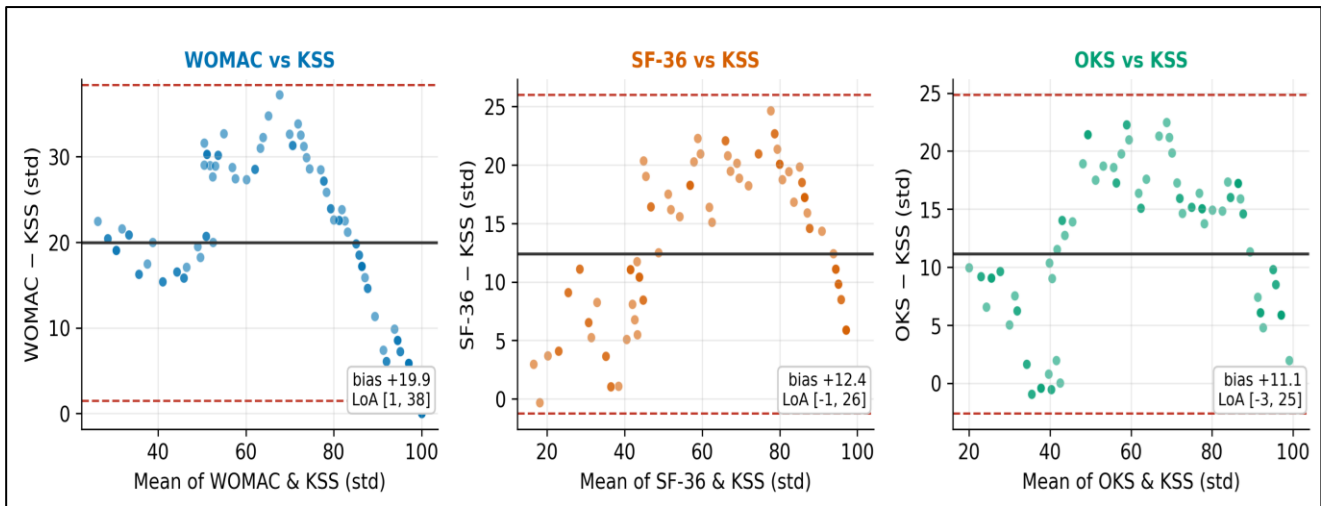


Figure 3: Bland-Altman agreement between PROMs and the KSS at 1 year (standardised scores).

*Solid line, mean bias; dashed lines, 95% limits of agreement. WOMAC carries the largest systematic offset; OKS the smallest.

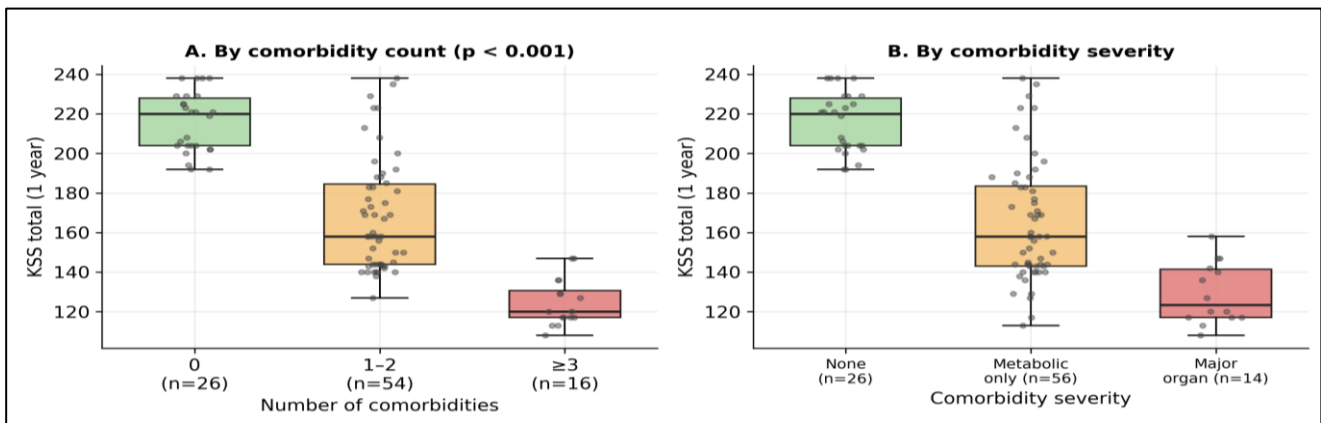


Figure 4 (A and B): One-year KSS outcome graded by comorbidity count (A) and severity (B).

*Outcome declines stepwise as burden rises ($p < 0.001$). Points are individual patients.

Table 1: Score trajectories and responsiveness (preoperative to 1 year).

Instrument (subscale)	Pre-op	3 weeks	1 year	ES	P value
KSS total	129.7 (27.5)	158.3 (37.1)	173.7 (38.0)	1.60	<0.001
OKS total	21.8 (8.6)	31.1 (10.0)	35.6 (10.2)	1.62	<0.001
WOMAC total	48.7 (18.4)	68.0 (17.3)	78.3 (16.3)	1.61	<0.001
SF-36 total	79.5 (24.6)	105.7 (26.8)	120.3 (26.2)	1.66	<0.001
KSS pain	3.7 (2.2)	7.8 (2.9)	9.9 (2.6)	2.89	<0.001
WOMAC pain	8.4 (3.7)	14.4 (3.3)	17.5 (2.7)	2.48	<0.001
OKS pain	6.6 (3.6)	10.2 (3.3)	12.0 (3.1)	1.50	<0.001

*Values are mean (SD). ES, standardised effect size (mean change/ baseline SD); p, Wilcoxon signed-rank test for preoperative-to-1-year change.

Table 2: Triage accuracy of remotely-collected PROMs for clinician-defined suboptimal outcome at 1 year.

PROM	AUC (95% CI)	Cut-off	Sens %	Spec %	NPV %	K	FN
OKS	0.98 (0.96-1.00)	<28	100	93	100	0.88	0
WOMAC	0.98 (0.96-1.00)	<69	100	91	100	0.85	0
SF-36	0.98 (0.96-1.00)	<105	100	86	100	0.77	0

*Suboptimal outcome pre-specified as lowest-quartile 1-year KSS ($n=26$, 27%). Cut-offs by the Youden index on standardised totals. AUC, area under the ROC curve; Sens, sensitivity; Spec, specificity; NPV, negative predictive value; κ , Cohen's kappa for decision-concordance; FN, false-negatives.

Table 3: Independent predictors of a suboptimal 1-year outcome (multivariable logistic regression).

Predictors	Adjusted OR (95% CI)	P value
Comorbidity count (per condition)	4.01 (1.79-8.99)	<0.001
Age (per year)	1.21 (1.04-1.40)	0.013
Male sex	1.19 (0.31-4.55)	0.804

*Model adjusted for age, sex and comorbidity count. OR, odds ratio. One-year KSS also fell stepwise across comorbidity strata (0: 215.6; 1-2: 168.0; ≥ 3 : 124.6; Kruskal–Wallis $p < 0.001$).

DISCUSSION

The principal finding of this study is operational rather than merely statistical: after the routine 3-week wound review, a questionnaire that a patient completes at home can reproduce the surgeon's triage decision closely enough-and safely enough-to replace a proportion of in-person visits, provided that follow-up intensity is matched to comorbidity burden.

Earlier studies, including our own initial analysis, asked how well PROMs correlate with a clinician score and reported coefficients close to unity. We deliberately moved past that question. Because the KSS already contains patient-reported elements and all of these instruments measure a shared pain-function construct, near-perfect correlation is expected and uninformative.^{5,6}

The more demanding test is agreement, and here Bland-Altman analysis was revealing: despite correlations above 0.93, the PROMs differed from the KSS by a systematic, clinically relevant margin-nearly 20 standardised points for WOMAC-so the scores cannot be used interchangeably or converted naively from one to another.¹³

The OKS showed the least bias and the tightest limits of agreement, and on that basis is the most defensible single instrument for remote knee surveillance.

Reframed as a triage test, the OKS performed in a way that matters clinically. Its 100% negative predictive value and absence of false-negatives mean that a reassuring remote OKS reliably excluded the clinician-defined poor outcome; in this cohort such patients could have safely deferred a clinic visit, while the roughly one-quarter of patients who screened positive-accepting some over-referral-would still have been seen.

For a high-volume service this is the right asymmetry of error: the cost of an unnecessary visit is far lower than the cost of missing a failing knee.

These cut-offs are concurrent and cohort-derived, however, and we present them as hypotheses for external testing against established minimal clinically important differences rather than as the ready-made decision rules.^{10,14,20}

The second novel element is the role of comorbidity. Comorbidity burden independently predicted a poor outcome and graded the 1-year result in a clear dose-response manner, by both number and severity, consistent with prior reports that comorbidity worsens arthroplasty outcomes.²¹

This converts a generic protocol into a stratified one: patients with no or metabolic-only comorbidity are well suited to predominantly remote follow-up, whereas those with three or more conditions or major-organ disease-who start lower, recover less and carry more risk-are better retained in a conventional in-person pathway.

Figure 5 integrates the timepoint-specific and comorbidity-specific findings into a single pragmatic pathway, in which an annual radiograph is retained for all patients so that a questionnaire is never asked to detect a radiographically silent complication on its own.²³ Such a hybrid model aligns with the wider shift toward telemedicine and remote monitoring in arthroplasty and could be strengthened in future by objective wearable-sensor data.^{7,9,28}

Our study has clear limitations, several of which define the next steps. It is a single-centre cohort from western India with a high comorbidity burden, which both limits generalisability and, equally, makes it directly relevant to the resource-constrained settings where remote follow-up is most needed; multicentre replication in other populations is essential.

The PROMs and the KSS share substantial variance and the triage reference standard was itself derived from the KSS, so the accuracy estimates are best regarded as concurrent validity and are likely optimistic; prospective validation against hard endpoints such as reoperation, infection and radiographic failure is required.

Follow-up extended only to 1 year, so late complications such as polyethylene wear and aseptic loosening were not captured; we are continuing the cohort to a minimum of two years. We did not include a parallel in-person-only control arm, body mass index was not recorded, and being patient-reported the PROMs may miss subclinical pathology. Finally, the proposed cut-offs need external calibration before clinical use.

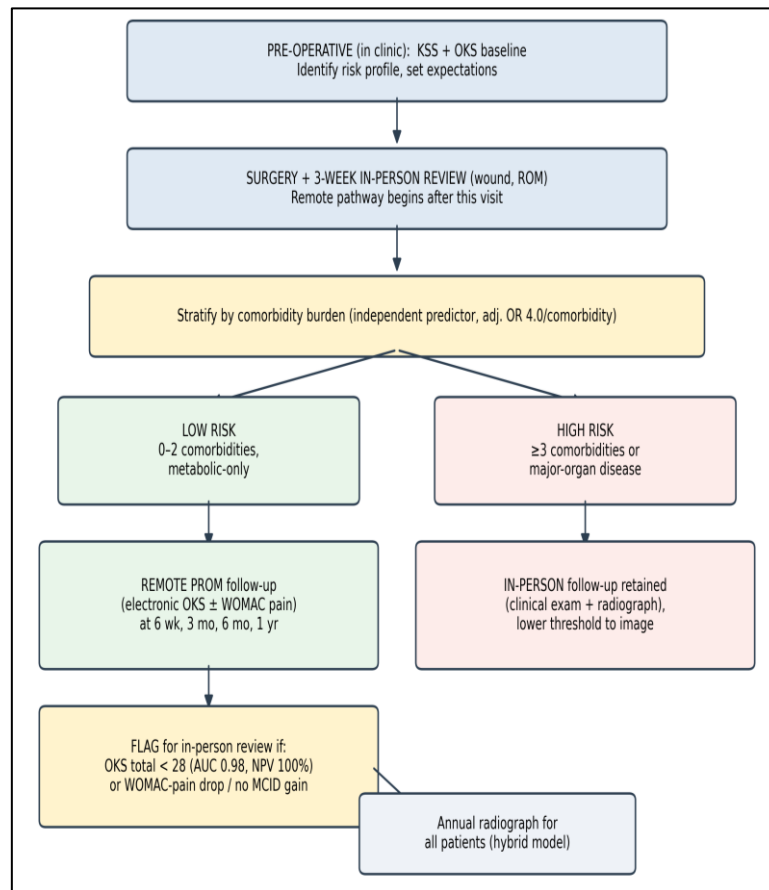


Figure 5: Proposed comorbidity-stratified remote triage pathway after TKA.

CONCLUSION

After the 3-week postoperative visit, a remotely-collected OKS agrees with the clinician-administered KSS closely enough to act as a triage tool and, in this cohort, identified every clinician-defined poor outcome while sparing unnecessary visits in the remainder. Because comorbidity burden independently graded both risk and outcome, follow-up intensity should be stratified by it. We propose a comorbidity-stratified hybrid pathway-remote PROM surveillance for low-risk patients, retained in-person review for high-risk patients, and an annual radiograph for all-and call for multicentre, longer-term and externally-validated studies, ideally incorporating wearable sensors, to confirm and refine it.

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Ethical approval: The study was approved by the Institutional Ethics Committee IEC approval No: IEC/ORTHO/04/2022).

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