Research Square

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An Efficiency Curve, Not a Safety Curve: Outcomes of Fellowship-Trained Surgeons in Their First 100 Direct Anterior THAs

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Abstract

Introduction: The direct-anterior-approach (DAA) for total hip arthroplasty (THA) has significant benefits but has historically been associated with a steep learning curve. However, modern training in the approach may eliminate that learning curve. We hypothesize that newly graduated surgeons with specific training in the DAA would show no difference in complication rates compared to senior DAA surgeons.

Methods: This retrospective cohort study included 600 primary THAs performed via a DAA from a single institution between November 2019 and February 2025 with a minimum of 90-day follow up. Intra- and post-operative complications were compared between the following two groups: the first 100 cases of each of three junior fellowship-trained arthroplasty surgeons (“Junior”) and the most recent 300 cases of a senior fellowship-trained arthroplasty surgeon (“Senior”).

Results: The incidence of operative complications was low and showed no significant difference between groups (Junior − 30 (10.0%) vs Senior − 23 (7.7%), p = 0.39). Subgroup analyses showed no between-group differences for DVT (1.3 vs 0.7%, p = 0.686), PE (0.7 vs 0.3%, p = 1.000), hematoma (0.3 vs 1.0%, p = 0.62), dislocation (1.3 vs 0.3%, p = 0.37), periprosthetic fracture (1.7 vs 1.0%, p = 0.73), neuropraxia (1.3 vs 2.0%, p = 0.75), prosthetic joint infection (1.0 vs 0.3%, p = 0.62), or wound complications (2.3 vs 2.3%, p = 1.00) (Table 2). Medical events were infrequent, with a non-significant trend toward more events in the Senior cohort (Junior − 7 (2.3%) vs Senior − 14 (4.7%), p = 0.181). Operative time was found to be longer among Junior surgeons (92.3 vs 68.5 minutes, p < 0.0001). No difference in patient reported outcome measures (PROMs) were found at 90 day follow up between junior and senior surgeon cohorts.

Conclusion: The results of this study suggest that while fellowship-trained DAA surgeons starting practice have longer operative times, there is no difference in overall complication rates or patient-reported functional outcomes when compared to a Senior DAA surgeon. This demonstrates that the historical learning curve surrounding adoption of the DAA may not apply with exposure to the approach during adult-reconstruction fellowship training.

Introduction

Total hip arthroplasty (THA) is among the most successful procedures in orthopedic surgery, offering durable pain relief and functional restoration for end-stage hip disease [1]. The direct anterior approach (DAA), utilizing an intermuscular and internervous plane, has gained significant popularity over the past decade due to reports of reduced soft-tissue disruption, lower dislocation rates, and accelerated early recovery [2–4]. This trend is reflected in a large AAHKS member survey (996 respondents), in which 56.2% reported performing the DAA, with adopters tending to be earlier in practice, consistent with an ongoing generational shift toward the approach [5].

Early in adoption of the DAA, studies exhibit complication patterns that cluster around femoral preparation, soft tissue handling and component positioning. Intraoperative femoral fractures; typically calcar, greater trochanteric (GT), and diaphyseal splits during exposure, broaching, or stem insertion have been shown to be increased in early experience and decline with volume [6–9]. Lateral femoral cutaneous nerve neurapraxia and associated meralgia paresthetica has also commonly been shown to present at higher rates early in practice. This is hypothesized to be due to the LFCN crossing the anterior field near the ASIS, making it vulnerable to retractor pressure and soft-tissue tension [8,9, 11–14]. Component malpositioning, particularly of the acetabular component, has also been shown to occur more frequently early in a surgeon's transition to DAA as they mature in their workflow and table setup, predisposing to impingement, anterior instability/dislocation, leg-length discrepancy, and early wear [15,16].

Superficial wound complications have also been reported more frequently early in practice, plausibly related to longer operative times and unoptimized soft-tissue protocols [7,17]. Collectively, composite reoperation and revision risk concentrates within the first 50–100 DAA cases and is largely driven by fractures and malposition [6,7,9,10].

Importantly, most prior investigations assessed experienced arthroplasty surgeons converting to the DAA mid-career, often without formal fellowship training in the approach. Emerging literature suggests that dedicated fellowship training may mitigate or eliminate this historical learning curve, yet no study has directly compared newly-graduated fellowship-trained surgeons performing their first independent cases against established senior DAA surgeons. We hypothesize that junior surgeons with specific DAA fellowship training would demonstrate no difference in complication rates compared to their senior counterparts.

Methods

Data Collection.

This retrospective cohort study included 600 primary, elective DAA total hip arthroplasty cases performed at a single academic institution between November 2019 and February 2025. Group 1 ("Junior") consisted of the first 100 consecutive primary DAA cases performed by each of three junior fellowship-trained arthroplasty surgeons, resulting in 300 hips. Group 2 ("Senior") consisted of the most recent 300 consecutive DAA cases performed by a single senior fellowship-trained surgeon. All four surgeons perform the DAA exclusively as their standard approach for primary elective THA, and all cases represented consecutive, unselected all-comer patients who were considered candidates for elective total hip arthroplasty. All procedures were performed with intraoperative fluoroscopy for component positioning verification; three surgeons performed cases off-table while one junior surgeon performed cases on-table using a standard fracture table.

Importantly, all junior surgeons were fully integrated into the institution's established enhanced recovery after surgery (ERAS) protocols from the outset of their independent practice, utilizing the same

standardized perioperative pathways as the senior surgeon. These pathways included standardized multimodal analgesia, perioperative anticoagulation protocols, and early mobilization strategies, ensuring that junior surgeons operated within an optimized, protocol-driven perioperative environment rather than developing individualized practices independently. All elective, primary DAA THA procedures with at least 90 days of follow-up were included. THAs performed for fracture, any revision surgeries, and patients with incomplete 90-day follow-up data were excluded. All three junior surgeons completed North American arthroplasty fellowships emphasizing DAA instruction with over 100 DAA THA cases logged during their year-long fellowship. The senior surgeon is over ten years into practice and has routinely performed the DAA throughout their career.

Outcome Variables.

The primary outcomes were intra-operative and post-operative complications occurring within 90 days of surgery, including calcar fracture, dislocation, periprosthetic fracture, prosthetic joint infection, wound complications, and neuropraxia. Bursitis and tendonitis were not included as complications. Secondary outcomes included operative time, length of stay, and medical complications including deep venous thrombosis (DVT), pulmonary embolism (PE), anemia requiring transfusion, urinary retention, acute kidney injury, stroke, myocardial infarction, and death, as well as patient-reported outcome measures (PROMs). PROMs, including SF-12 Physical and Mental component scores and WOMAC pain, stiffness, and function subscales, were collected preoperatively and at 90 days postoperatively using routinely administered institutional questionnaires. Operative time was calculated from surgical time out to the end of surgical closure.

Data Analyses.

Continuous variables were compared using Student's t-test, while categorical variables were compared using chi-square or Fisher's exact tests as appropriate. A priori power analysis concluded that a minimum of 269 patients per group would be sufficient to detect a 5% difference in overall complication rates given an alpha of 0.05 and 80% power [20].

Ethical Approval.

This study received institutional review board approval: IRB-AAAV1356.

Results

Patient Demographics

A total of 600 patients were included in this study: 300 cases performed by three junior fellowship-trained surgeons and 300 cases performed one fellowship trained senior surgeon. Demographic characteristics are summarized in **Table 1**. The cohorts were well matched for BMI (27.9 ± 5.32 vs 27.9 ± 5.24 kg/m², p=0.947) and ASA classification (2.3 ± 0.68 vs 2.4 ± 0.54, p=0.350). A statistically significant

difference in mean age was identified, with senior cohort patients being older than junior cohort patients (62.7 ± 12.86 vs 67.6 ± 9.49 years, p<0.001). This difference was adjusted for in all multivariate analyses.

Operative Complications

Operative complications at 90-day follow-up are presented in **Table 2**. The incidence of operative complications was low and showed no significant difference between groups (Junior - 30 (10.0%) vs Senior - 23 (7.7%), p=0.39). Dislocation was observed in 4 junior patients (1.3%) and 1 senior patient (0.3%, p=0.373). Periprosthetic fracture occurred in 5 junior (1.7%) and 3 senior patients (1.0%, p=0.725). Neuropraxia was identified in 4 junior (1.3%) and 6 senior patients (2.0%, p=0.752). Prosthetic joint infection occurred in 3 junior patients (1.0%) and 1 senior patient (0.3%, p=0.624). Wound complications were equally distributed between groups (7 [2.3%] vs 7 [2.3%], p=1.000). One mortality occurred in each cohort (0.3% vs 0.3%, p=1.000). Unplanned return to the operating room was required in 5 junior patients (1.7%) and 4 senior patients (1.3%, p=1.000). Fisher's Exact Test was used for all categorical comparisons given low expected cell frequencies.

Medical Complications

Medical complications at 90-day follow-up are presented in **Table 3.** No statistically significant differences were identified between groups for any individual medical complication. Pulmonary embolism occurred in 2 junior patients (0.7%) versus 1 senior patient (0.3%, p=1.000). Deep vein thrombosis occurred in 4 junior patients (1.3%) versus 2 senior patients (0.7%, p=0.686). Transfusion was required in 5 junior patients (1.7%) versus 3 senior patients (1.0%, p=0.725). Stroke occurred in 1 junior patient (0.3%) and 2 senior patients (0.7%, p=1.000). Acute kidney injury was observed in 2 junior patients (0.7%) and 3 senior patients (1.0%, p=1.000). Urinary retention occurred in 1 junior patient (0.3%) and 3 senior patients (1.0%, p=0.624). Myocardial infarction and pneumonia were each absent in the junior cohort and each occurred in 1 senior patient (p=1.000 for both). In total, 45 total complications were recorded among the 300 THAs in the junior cohort (15.0%) versus 42 total complications across the senior cohort (14.0%) (p=0.817).

Multivariate Analysis - Complication Risk

To evaluate the independent effect of surgeon experience on 90-day complication risk while accounting for the observed age difference between cohorts, logistic regression was performed adjusting for age, BMI, and ASA classification **Table 4**. Surgeon group was not a significant independent predictor of any complication at 90 days (OR 0.77, 95% CI 0.44-1.35, p=0.357). Age, BMI, and ASA class were also not significant independent predictors of complication risk in this model (p=0.070, p=0.326, and p=0.137, respectively).

Operative Time

Operative time data are presented in **Table 5**. Mean operative time for the junior cohort combined was 92.3 ± 24.5 minutes (median 88 minutes, range 56-237) compared with 68.5 ± 16.2 minutes for the

senior surgeon (median 68 minutes, range 36-141; p<0.001, Mann-Whitney U), a mean difference of 23.8 minutes.

Sequential quartile analysis demonstrated a significant efficiency learning curve across all junior surgeons **Table 6**. Combined junior Q1 mean operative time was 108.3 ± 24.5 minutes, declining to 84.6 ± 19.2 minutes in Q4 (ANOVA F=17.35, p<0.001; Q1 vs Q4 p<0.001). There was no statistically significant difference in operative time between the three junior surgeons (p=0.11, Kruskal-Wallis). In contrast, the senior surgeon's operative time was stable across all four equal 75-case blocks (68.6, 72.0, 65.9, and 67.5 minutes, delta = -1.1 minutes), with no significant trend, consistent with an established operative plateau.

Multivariate Analysis - Operative Time

Linear regression modelling of operative time is presented in **Table 7**. After adjusting for age, BMI, and ASA classification, junior surgeons performed cases a mean of 24.6 minutes longer than the senior surgeon (95% CI +21.2 to +28.1, p<0.001). Higher BMI was independently associated with longer operative time, with each unit increase adding 0.6 minutes (95% CI +0.3 to +0.9, p<0.001), consistent with increased technical complexity in higher body habitus patients undergoing the direct anterior approach. Age and ASA class were not significant independent predictors of operative time (p=0.217 and p=0.081, respectively).

Patient-reported outcomes.

At baseline, patients treated by junior surgeons had significantly worse SF-12 physical and WOMAC scores than those treated by the senior surgeon, whereas SF-12 mental scores were similar between cohorts. Preoperatively, SF-12 physical scores averaged 37.4 in the junior cohort and 41.1 in the senior cohort (p < 0.001). WOMAC pain, stiffness, and function scores were also lower (worse) in the junior cohort (38.0, 39.7, and 37.0, respectively) compared with the senior cohort (49.7, 51.6, and 50.2; all p < 0.001). In contrast, SF-12 mental scores were nearly identical at baseline (47.1 vs 46.9 for junior vs senior cohorts, p = 0.82) **Table 8**.

By 90 days, both cohorts demonstrated large improvements in pain and function, and cross-sectional PROMs were similar between junior and senior surgeons. SF-12 physical scores at 90 days were 46.2 in the junior cohort and 46.7 in the senior cohort (p = 0.63), and SF-12 mental scores were 47.6 versus 46.5 (p = 0.17). WOMAC pain, stiffness, and function at 90 days were likewise comparable between groups (pain 87.4 vs 89.2, p = 0.40; stiffness 76.0 vs 78.8, p = 0.29; function 81.8 vs 84.1, p = 0.31 for junior vs senior cohorts, respectively) **Table 8.**

In the subset of patients with paired preoperative and 90-day follow-up data, absolute improvements in several PROMs were greater in the junior cohort. Among 102 junior and 143 senior patients with paired SF-12 physical scores, SF-12 physical increased by 8.6 points in the junior cohort compared with 6.2 points in the senior cohort (p = 0.029). Improvements in WOMAC pain and function were also

significantly larger for junior surgeons, with WOMAC pain increasing by 50.1 vs 38.1 points (n = 102 and 141, respectively; p < 0.001) and WOMAC function increasing by 44.4 vs 32.9 points (p < 0.001). Differences in absolute change for SF-12 mental (0.1 vs -0.5 points; p = 0.58) and WOMAC stiffness (36.3 vs 28.9 points; p = 0.07) were not statistically significant. Thus, although junior surgeons operated on patients with worse baseline pain and functional limitation, these patients experienced at least comparable and in several domains significantly greater absolute improvements, achieving 90-day PROMs that were indistinguishable from those of patients treated by the senior surgeon **Table 8.**

The following patient-reported outcome analyses are considered exploratory given the 90-day follow-up rate of 35% in the junior cohort and 48% in the senior cohort; these results should be interpreted with caution as non-response bias cannot be excluded

Discussion

Historically, the DAA has been characterized by reports of increased complications during the early adoption phase with improved outcomes over the first 50-100 procedures in independent practice. This has particularly been described among surgeons who did not receive exposure to the DAA during their fellowship training and transitioned to the approach while in practice [6-7]. However, our findings suggest that the increasing exposure to the DAA during training effectively debunks the traditionally described learning curve associated with this approach. While junior surgeons had longer operative times, demonstrating an efficiency curve still exists, we found no significant difference in safety outcomes based on experience.

In contrast to prior series describing an early DAA “safety” learning curve, with clustered events such as intra-operative femoral fractures, lateral femoral cutaneous nerve neurapraxia, component malposition, and superficial wound complications during the first ~50-100 cases [6-17]; our study demonstrated junior surgeons’ complication rates were comparable to a senior, high-volume DAA surgeon despite longer operative times (overall complications 10.0% vs 7.7%, p=0.39). Although the junior cohort had a numerically higher overall complication rate (10.0% vs 7.7%), this 2.3% absolute difference did not reach statistical significance (p = 0.39). The study was powered to detect a 5% absolute difference in complications; thus, these data support the absence of a large difference in overall complication rates between junior and senior surgeons, but do not exclude the possibility of smaller differences that this study was not designed to detect.

Several features of our modern surgical environment plausibly account for the divergence from historical patterns, with our study focusing on the effect of dedicated fellowship exposure to the DAA. Several contemporary analyses suggest that formal DAA training during fellowship significantly mitigates the traditional safety learning curve, even if time-based metrics and certain technical endpoints continue to show early variation. Burnham et al. conducted a multicenter retrospective study of 286 DAA THAs performed by four fellowship-trained surgeons in their first year of independent practice, finding that fellowship training eliminated learning curve effects for operative time and blood loss; however, a

complication-based learning curve persisted, with surgical complications declining after approximately 40 cases and medical complications normalizing between 25-50 cases [18]. Notably, our study extends beyond these findings, as we observed no significant difference in complication rates between junior and senior surgeons, suggesting that continued evolution in fellowship training intensity and institutional perioperative infrastructure may further compress the safety curve that Burnham's cohort still experienced.

Garbarino et al. prospectively followed the first 200 consecutive DAA THAs performed by a single fellowship-trained surgeon, demonstrating persistent intra-cohort differences in operative time, acetabular component positioning, and neuropraxia rates between the first and second 100 cases [19]. Importantly, however, their comparison to the broader historical literature revealed that fellowship training substantially reduced early fracture and reoperation rates relative to non-fellowship-trained cohorts, a pattern consistent with our own finding of comparable complication rates between junior and senior surgeons. The neuropraxia signal observed by Garbarino, dropping from 41% in the first 100 cases to 9% in the second 100 cases, was not replicated in our cohort, which may reflect further refinement in retractor technique and soft-tissue management taught during contemporary fellowship training.

Messina et al. directly addressed whether the DAA carries a steeper learning curve than the posterolateral approach among newly fellowship-trained surgeons, analyzing the first 100 cases of six fellowship-trained surgeons across both approaches [20]. They found no significant differences in revision rates, surgical complications, or total complications between DA and PL surgeons, though both groups demonstrated higher complication rates in their first 50 cases compared to their second 50 cases. While Messina's findings confirm that fellowship training produces equivalent early safety profiles across approaches, the persistent first-50-case complication signal across both groups contrasts with our observation of no significant difference between junior and senior DAA surgeons even from the outset, again suggesting that institutional factors beyond fellowship training alone; including standardized ERAS pathways and high-volume center experience may play an additive role in further flattening the learning curve.

At the same time, modern enhanced-recovery after surgery (ERAS) and standardized perioperative protocols likely contribute to the leveling of safety differences across experience levels by reducing variability and preventing common early pitfalls; this is supported by ERAS recommendations and reviews in arthroplasty [21-23]. ERAS consensus statements for THA/TKA and subsequent reviews associate protocolized care with shorter stays and reductions in complications and cost [21]. In settings where fellowship training and ERAS infrastructure co-evolve, the between-surgeon differences in complications may narrow further, leaving operative time as the main early differentiator.

From a patient-centered perspective, these exploratory PROM data complement our complication and operative time findings, though they should be interpreted with caution given 90-day follow-up rates below 50% in both cohorts. Despite operating on patients with significantly worse preoperative pain, stiffness, function, and physical health status, junior fellowship-trained DAA surgeons achieved 90-day

SF-12 and WOMAC scores that were comparable to those of a senior high-volume DAA surgeon in this exploratory analysis. This pattern of worse baseline symptoms but convergence of outcomes by early follow-up suggests that, within a modern system emphasizing DAA-specific fellowship training and standardized perioperative pathways, there may be no clinically meaningful functional penalty associated with care by junior surgeons, though prospective studies with higher follow-up rates are needed to confirm this finding. Instead, the learning curve appears confined primarily to efficiency, with longer operative times but equivalent short-term patient-reported recovery in this cohort. These exploratory findings are consistent with our overall observation that contemporary fellowship training may flatten the traditional DAA learning curve by mitigating early complications and standardizing recovery trajectories.

This study is not without limitations. We did not account for potential confounding variables such as case complexity and our 90-day follow-up window may not be long enough to capture later-onset complications such as late dislocation, aseptic loosening, or revision. Furthermore, this was a single-institution study in a high-volume arthroplasty center with established ERAS pathways, which may limit generalizability to centers with different perioperative infrastructure. The mean BMI of our cohort was comparable between groups (28.0 vs 27.9, junior vs senior cohort; $p = 0.82$), but was relatively low compared to national averages for THA patients in the United States. This may reflect institutional referral and selection patterns, and could limit generalizability of our findings to higher-BMI populations where soft-tissue management and surgical complexity are inherently greater for the DAA. Although we incorporated SF-12 and WOMAC patient-reported outcome measures, these data were available only for a subset of patients at 90-days, raising the possibility of response bias if non-responders differed systematically from responders. Available demographic data for 90-day PROM completers versus non-completers showed no significant differences in age, BMI, or ASA classification in either cohort (all $p > 0.05$), providing limited reassurance against non-response bias; however, pre-operative functional status could not be compared between responders and non-responders given the nature of the missing follow-up data, and response bias related to functional outcome cannot be fully excluded. Additionally, we did not analyze radiographic measures of implant positioning, offsets, or leg-length discrepancy, which remain important endpoints for future investigation. Lastly, our power analysis was based on detecting a 5% absolute difference in overall complication rates. While our final sample size exceeded this target and was adequate for the primary outcome, the study remains underpowered to detect smaller absolute differences in complications and to evaluate individual rare adverse events. Accordingly, subgroup complication analyses and PROM comparisons should be interpreted as exploratory.

Conclusion

In this single-institution cohort, fellowship-trained junior surgeons performing their first 100 DAA THAs in practice demonstrated complication and medical event rates comparable to those of a high-volume senior DAA surgeon, despite longer operative times and more symptomatic patients at baseline. By 90 days, SF-12 and WOMAC scores were similar between groups, and patients treated by junior surgeons achieved greater absolute improvements in WOMAC pain and function in this exploratory analysis,

suggesting no functional penalty associated with care by early-career DAA surgeons. Taken together, these findings indicate that in the context of dedicated DAA-focused fellowship training and standardized perioperative pathways, the contemporary DAA "learning curve" is largely one of efficiency rather than safety or outcome, and that training quality and institutional infrastructure may be more critical determinants of early outcomes than surgeon seniority alone.

Declarations

Ethics approval and consent to participate: This study received institutional review board approval (IRB-AAAV1356). As a retrospective cohort study using existing medical record data, the requirement for individual patient consent was waived by the IRB.

Consent for publication: Not applicable.

Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Authors' contributions:

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C.L.H.: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – review & editing.

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Tables

Table 1

Demographic Characteristics by Surgeon Group

Variable	Junior Surgeons (n = 300)	Senior Surgeon (n = 300)	p-value
Age, years	62.7 ± 12.86	67.6 ± 9.49	< 0.001
BMI, kg/m²	27.9 ± 5.32	27.9 ± 5.24	0.947
ASA class	2.3 ± 0.68	2.4 ± 0.54	0.350
Values are mean ± SD. p-values from Welch's independent samples t-test.			

Table 2

Operative Complications at 90-Day Follow-Up

Complication	Junior n (%)	Senior n (%)	p-value
Hematoma	1 (0.3%)	3 (1.0%)	0.624
Dislocation	4 (1.3%)	1 (0.3%)	0.373
Periprosthetic fracture	5 (1.7%)	3 (1.0%)	0.725
Neuropraxia	4 (1.3%)	6 (2.0%)	0.752
Prosthetic joint infection	3 (1.0%)	1 (0.3%)	0.624
Wound complication	7 (2.3%)	7 (2.3%)	1.000
Mortality	1 (0.3%)	1 (0.3%)	1.000
Return to OR	5 (1.7%)	4 (1.3%)	1.000
Fisher's Exact Test throughout. OR = operating room.			

Table 3

Medical Complications and Overall Complication Rate at 90-Day Follow-Up

Complication	Junior n (%)	Senior n (%)	p-value
Deep vein thrombosis	4 (1.3%)	2 (0.7%)	0.686
Pulmonary embolism	2 (0.7%)	1 (0.3%)	1.000
Anemia requiring transfusion	5 (1.7%)	3 (1.0%)	0.725
Myocardial infarction	0 (0.0%)	1 (0.3%)	1.000
Stroke	1 (0.3%)	2 (0.7%)	1.000
Pneumonia	0 (0.0%)	1 (0.3%)	1.000
Urinary retention	1 (0.3%)	3 (1.0%)	0.624
Acute kidney injury	2 (0.7%)	3 (1.0%)	1.000
Any complication	45 (15.0%)	42 (14.0%)	0.817

Fisher's Exact Test. Any complication reflects patients with at least one complication of any type, operative or medical.

Table 4

Logistic Regression - Any Complication at 90 Days (n = 593)

Variable	OR	95% CI	p-value
Surgeon group (Junior vs Senior)	0.77	0.44–1.35	0.357
Age (per year)	1.02	1.00-1.05	0.070
BMI (per unit)	1.03	0.97–1.08	0.326
ASA class (per point)	1.45	0.89–2.35	0.137

Reference group: senior surgeon. OR = odds ratio; CI = confidence interval. Pseudo-R^2 (McFadden) = 0.022.

Table 5

Operative Time by Surgeon

Surgeon	Mean ± SD, min	Median	Range, min	n
Junior Surgeon 1	97.3 ± 27.6	92	56–237	100
Junior Surgeon 2	93.0 ± 24.9	90	56–188	100
Junior Surgeon 3	86.7 ± 19.5	86	56–162	100
Junior Combined	92.3 ± 24.5	88	56–237	300
Senior Surgeon	68.5 ± 16.2	68	36–141	300
Junior combined vs Senior: $p < 0.001$, Mann-Whitney U.				

Table 6

Operative Time Learning Curve by Quartile (mean ± SD, minutes)

Surgeon	Q1 (Cases 1–25 (Junior) & Cases 1–75 (Senior)), min	Q2 (Cases 26–50 (Junior) & Cases 76–150 (Senior))min	Q3 (Cases 51–75 (Junior) & Cases 151–225 (Senior))	Q4 (Cases 76–100 (Junior) & Cases 226–300 (Senior))
Junior Surgeon 1	120.0 ± 24.9	88.6 ± 16.9	96.0 ± 34.3	84.5 ± 16.2
Junior Surgeon 2	108.0 ± 28.1	86.4 ± 17.5	89.8 ± 23.9	87.6 ± 23.9
Junior Surgeon 3	97.0 ± 15.8	83.1 ± 16.8	85.2 ± 24.5	81.7 ± 17.0
Junior Combined	108.3 ± 25.1	86.0 ± 17.0	90.3 ± 28.0	84.6 ± 19.2
Senior Surgeon	68.6 ± 16.8	72.0 ± 18.0	65.9 ± 15.2	67.5 ± 14.2
Quartile analysis uses sequential case order per surgeon.				

Table 7

Linear Regression - Operative Time in Minutes (n = 572)

Variable	β, min	95% CI	p-value
Surgeon group (Junior vs Senior)	+ 24.6	+ 21.2 to + 28.1	< 0.001
Age (per year)	+ 0.1	-0.1 to + 0.3	0.217
BMI (per unit)	+ 0.6	+ 0.3 to + 0.9	< 0.001
ASA class (per point)	+ 2.5	-0.3 to + 5.4	0.081

Reference group: senior surgeon. β = unstandardized regression coefficient. R^2=0.277, adjusted R^2=0.272.

Table 8

Patient reported outcome measures pre-operatively and at 90-day follow up, including SF and WOMAC metrics.

PROM	Time point	Junior (mean ± SD, n)	Senior (mean ± SD, n)	p-value (Junior vs Senior)
SF-12 Physical	Pre-op	37.35 ± 7.90 (n = 262)	41.15 ± 7.49 (n = 284)	< 0.001
	3-month	46.24 ± 7.63 (n = 105)	46.70 ± 7.32 (n = 144)	0.630
	Change (3-month - pre-op)	8.59 ± 8.92 (n = 102)	6.20 ± 7.50 (n = 143)	0.029
SF-12 Mental	Pre-op	47.06 ± 6.20 (n = 262)	46.93 ± 7.19 (n = 284)	0.822
	3-month	47.62 ± 5.70 (n = 105)	46.51 ± 6.97 (n = 144)	0.169
	Change (3-month - pre-op)	0.11 ± 8.12 (n = 102)	-0.48 ± 8.54 (n = 143)	0.584
WOMAC Pain	Pre-op	38.02 ± 21.55 (n = 260)	49.74 ± 20.67 (n = 278)	< 0.001
	3-month	87.43 ± 16.23 (n = 105)	89.15 ± 15.10 (n = 143)	0.396
	Change (3-month - pre-op)	50.15 ± 24.28 (n = 102)	38.12 ± 23.20 (n = 141)	< 0.001
WOMAC Stiffness	Pre-op	39.73 ± 24.05 (n = 259)	51.64 ± 28.10 (n = 279)	< 0.001
	3-month	75.95 ± 20.78 (n = 105)	78.80 ± 21.63 (n = 146)	0.293
	Change (3-month - pre-op)	36.27 ± 31.93 (n = 102)	28.86 ± 31.89 (n = 142)	0.075
WOMAC Function	Pre-op	36.96 ± 19.18 (n = 258)	50.23 ± 23.59 (n = 278)	< 0.001
	3-month	81.78 ± 17.08 (n = 105)	84.14 ± 19.31 (n = 146)	0.307
	Change (3-month - pre-op)	44.40 ± 23.61 (n = 102)	32.91 ± 26.35 (n = 141)	< 0.001