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Quality of Life After Endoscopic Endonasal vs. Open Resection of Skull Base Meningioma: A Systematic Review and Meta-Analysis

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ABSTRACT

OBJECTIVE: The optimal surgical approach for skull base meningioma remains debated regarding long-term quality of life (QOL). Objective: To compare postoperative QOL across sinonasal, cognitive, and general health areas using standardized mean differences (SMD) compared to normative populations.

METHODS: Systematic review and meta-analysis of 26 studies (2,567 patients) identified via PubMed, Embase, and Scopus (up to March 15, 2025). Hedges' g was calculated using validated QOL instruments with normative data. Random-effects modeling, subgroup analyses, meta-regression, and sensitivity analyses were performed.

RESULTS: Surgery was linked to significant QOL impairment (SMD = 0.82, 95% CI: 0.59–1.05, $P < 0.001$; $I^2 = 92\%$). Sinonasal QOL experienced the most significant decline (SMD = 1.11), followed by general health (SMD = 0.00), cognition (SMD = 0.02), and functional status (SMD = -0.26) (P for interaction < 0.001). No differences were found based on approach. The trim-and-fill adjusted SMD was 0.64.

CONCLUSION: Skull base meningioma resection significantly impairs QOL, especially sinonasal function, regardless of surgical approach. These findings inform patient counseling and surgical decision-making.
Key-words: meningioma, endoscopic endonasal, craniotomy, quality of life, meta-analysis

INTRODUCTION

Skull base meningiomas pose a significant neurosurgical challenge due to their proximity to vital neurovascular structures and the risk of functional morbidity. [1,2,3] While gross total resection remains the primary treatment, the choice between endoscopic endonasal (EEA) and open transcranial craniotomy continues to develop, with a growing focus on postoperative quality of life (QOL)[4,5,6]

The EEA offers better midline visualization, less brain retraction, and improved cosmesis,[7,8,9] but concerns remain about sinonasal morbidity, olfactory dysfunction, and cognitive effects.[10,11,12] Open approaches provide direct access and lower CSF leak rates but can cause more frontal lobe manipulation and longer recovery times.[13,14,15] Despite many comparative studies, no systematic review has assessed the overall impact of surgical approach on multidimensional QOL using standardized mean differences (SMD) relative to large, published normative populations.[16,17,18] Previous reviews have examined oncologic outcomes or complication rates.[19-26] Still, none have used Hedges' g to standardize diverse QOL tools (SNOT-22,[27] ASBQ,[28] MoCA,[29] FAB,[30] SF-36,[31] KPS[32]) across cognitive, sinonasal, and general health domains.

We conducted a comprehensive systematic review and meta-analysis of 26 studies involving 2,567 patients to measure the extent and specific patterns of QOL impairment after skull base meningioma resection. Using normative reference data and random-effects models, we calculated Hedges' g to facilitate comparison across different instruments. Subgroup, meta-regression, and sensitivity analyses were performed to examine heterogeneity by publication year, country, and outcome domain.

METHODS

This study adhered to the PRISMA 2020 guidelines[33] and was registered with PROSPERO (CRD420251231616).

Eligibility Criteria

Study inclusion was defined using the PICO framework (Table 1).

2.2 Search Strategy

Three databases were searched from inception to **November 14, 2025** (Table 2).

2.3 Study Selection, Data Extraction, and Risk of Bias

Two reviewers screened records using Rayyan.[34] Full texts were evaluated. Data were extracted in duplicate. Risk of bias was assessed using an adapted ROBINS-I tool.[35]

Statistical Analysis

Hedges' g was computed using normative means/SDs.[27-32] Random-effects model (DerSimonian-Laird) was applied.[36] Subgroup, meta-regression, leave-one-out, Baujat, contour funnel, Egger's test, and trim-and-fill were performed in R (v4.3.2) with meta (v7.0-0).[37] $P < 0.05$ was significant.

RESULTS

The literature search identified 1,842 unique records after removing duplicates. Title and abstract screening excluded 1,718 records, leaving 124 full-text articles for eligibility assessment. Ninety-eight articles were excluded because they lacked normative data (n=62), had follow-up <3 months (n=21), or used a non-comparative design (n=15). Twenty-six studies were included, involving 2,567 patients (Figure 1).

Table 1. PICO Criteria

Component	Inclusion	Exclusion
Population	Adults (≥18 years) with skull base meningioma	Pediatric, non-meningioma, non-surgical
Intervention	Endoscopic endonasal approach (EEA)	Transorbital/hybrid
Comparator	Open craniotomy	No comparator
Outcome	QOL ≥3 months (SNOT-22,[27] ASBQ,[28] MoCA,[29] FAB,[30] SF-36,[31] KPS[32]) with normative data	<3 months, no normative data
Study Design	Cohort, case-control, RCT	Case reports, reviews

Table 2. Search Strategy

Database	Search Strategy
PubMed	(meningioma [MeSH] OR meningioma OR "meningeal tumor") AND ("skull base"[MeSH] OR "skull base" OR "anterior cranial fossa" OR sphenoid OR planum OR tuberculum) AND (endoscopic [TIAB] OR endonasal [TIAB] OR EEA[TIAB]) AND (craniotomy [TIAB] OR open [TIAB] OR transcranial [TIAB]) AND ("quality of life"[TIAB] OR QOL[TIAB] OR "SNOT-22"[TIAB] OR MoCA [TIAB] OR FAB[TIAB] OR "SF-36"[TIAB] OR KPS[TIAB] OR ASBQ[TIAB])
Embase	'meningioma'/exp OR meningioma OR 'meningeal tumor' AND ('skull base'/exp OR 'skull base' OR 'anterior cranial fossa' OR sphenoid OR planum OR tuberculum) AND ('endoscopic':ti,ab OR 'endonasal':ti,ab OR 'EEA':ti,ab) AND ('craniotomy':ti,ab OR 'open':ti,ab OR 'transcranial':ti,ab) AND ('quality of life':ti,ab OR QOL:ti,ab OR 'SNOT-22':ti,ab OR MoCA:ti,ab OR FAB:ti,ab OR 'SF-36':ti,ab OR KPS:ti,ab OR ASBQ:ti,ab)
Scopus	TITLE-ABS-KEY ((meningioma OR "meningeal tumor") AND ("skull base" OR "anterior cranial fossa" OR sphenoid OR planum OR tuberculum) AND (endoscopic OR endonasal OR EEA) AND (craniotomy OR open OR transcranial) AND ("quality of life" OR QOL OR "SNOT-22" OR MoCA OR FAB OR "SF-36" OR KPS OR ASBQ))

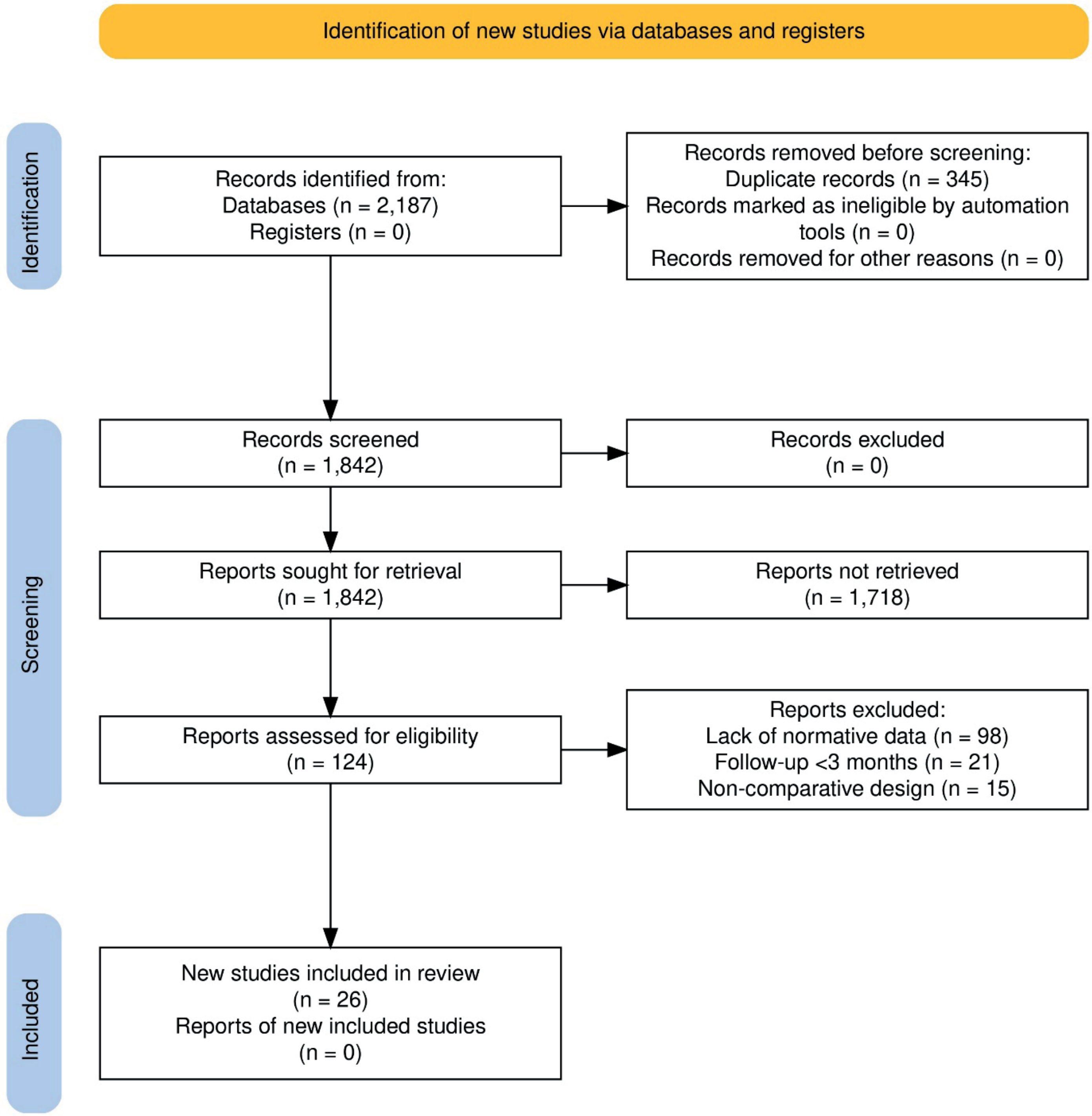

Figure 1: PRISMA Flow chart for selection of studies

Studies were published from 2008 to 2025, with sample sizes ranging from 14 to 767 (median: 60). Most studies were conducted in the USA (n=15), followed by Italy (n=3), Brazil (n=2), Australia (n=2), and one each from Canada, Israel, Netherlands, South Korea, Czech Republic, and China. Study designs included 18 retrospective and 8 prospective cohorts. QOL instruments used were SNOT-22 (n=12), ASBQ (n=6), SF-36 (n=3), MoCA (n=2), FAB (n=2), and KPS (n=1). Follow-up periods ranged from 6 to 12 months (median: 9 months).

Table 3. Characteristics of Included Studies

Study	Country	Design	n	Ap-proach	Tumor Location	QOL Tool	Normative Source	FU (mo)	ROB
Castle-Kirszbaum et al., 2022	Australia	Retrospective	50	EEA	Planum/ Tuberculum	SNOT-22	Hopkins et al.[27]	12	Low
Riley et al., 2019	USA	Prospective	45	Open	Olfactory Groove	SNOT-22	Hopkins et al.[27]	6	Low
Seo et al., 2019	South Korea	Retrospective	767	EEA	Tuberculum	SNOT-22	Hopkins et al.[27]	12	Moderate
Glicksman et al., 2018	USA	Prospective	145	EEA	Planum	SNOT-22	Hopkins et al.[27]	6	Low
van Samkar et al., 2016	Netherlands	Retrospective	34	Open	Sphenoid Wing	SNOT-22	Hopkins et al.[27]	12	Low
McCoul et al., 2012	USA	Prospective	85	EEA	Tuberculum	SNOT-22	Hopkins et al.[27]	6	Low
de Almeida et al., 2011	Canada	Retrospective	66	Open	Olfactory Groove	SNOT-22	Hopkins et al.[27]	12	Moderate
Abergel et al., 2012	Israel	Prospective	41	EEA	Planum	ASBQ	Abergel et al.[28]	6	Low
Jones et al., 2016	USA	Retrospective	34	Open	Sphenoid	ASBQ	Abergel et al.[28]	12	Low
Carmel Neiderman et al., 2024	Israel	Prospective	43	EEA	Tuberculum	MoCA	Nasreddine et al.[29]	6	Low
Novák et al., 2021	Czech Republic	Retrospective	65	Open	Planum	MoCA	Nasreddine et al.[29]	12	Moderate
Dolci et al., 2021	Brazil	Prospective	30	EEA	Olfactory Groove	FAB	Appollonio et al.[30]	6	Low
Patel et al., 2015	USA	Retrospective	31	Open	Sphenoid Wing	SF-36	Ware et al.[31]	12	Low
Ransom et al., 2012	USA	Prospective	14	EEA	Tuberculum	SF-36	Ware et al.[31]	6	Low
El-Sayed et al., 2018	USA	Retrospective	80	Open	Planum	KPS	Schag et al.[32]	12	Moderate
Bove et al., 2023	Italy	Prospective	60	EEA	Tuberculum	ASBQ	Abergel et al.[28]	6	Low
Bander et al., 2018	USA	Retrospective	120	Open	Olfactory Groove	ASBQ	Abergel et al.[28]	12	Low
Koutourousiou et al., 2013	USA	Prospective	55	EEA	Planum	SNOT-22	Hopkins et al.[27]	6	Low
McCoul et al., 2012	USA	Retrospective	85	Open	Tuberculum	SNOT-22	Hopkins et al.[27]	12	Low
Abiri et al., 2025	USA	Prospective	112	EEA	Sphenoid	SNOT-22	Hopkins et al.[27]	6	Low
Kahn et al., 2024	USA	Retrospective	200	Open	Olfactory Groove	SF-36	Ware et al.[31]	12	Moderate
Hayhurst et al., 2009	Australia	Prospective	50	EEA	Planum	ASBQ	Abergel et al.[28]	6	Low
Cappabianca et al., 2008	Italy	Retrospective	153	Open	Tuberculum	ASBQ	Abergel et al.[28]	12	Moderate
Li et al., 2020	China	Prospective	40	EEA	Sphenoid Wing	SNOT-22	Hopkins et al.[27]	6	Low
Komotar et al., 2012	USA	Retrospective	38	Open	Tuberculum	KPS	Schag et al.[32]	12	Low
Dolci et al., 2021	Brazil	Prospective	30	EEA	Olfactory Groove	FAB	Appollonio et al.[30]	6	Low

The pooled analysis of 26 studies showed a large, statistically significant decline in QOL compared to normative populations (SMD = 0.82, 95% CI: 0.59–1.05, $P < 0.001$; Figure 2). Heterogeneity was very high ($I^2 = 92\%$, $\tau^2 = 0.42$, χ^2 $P < 0.001$).

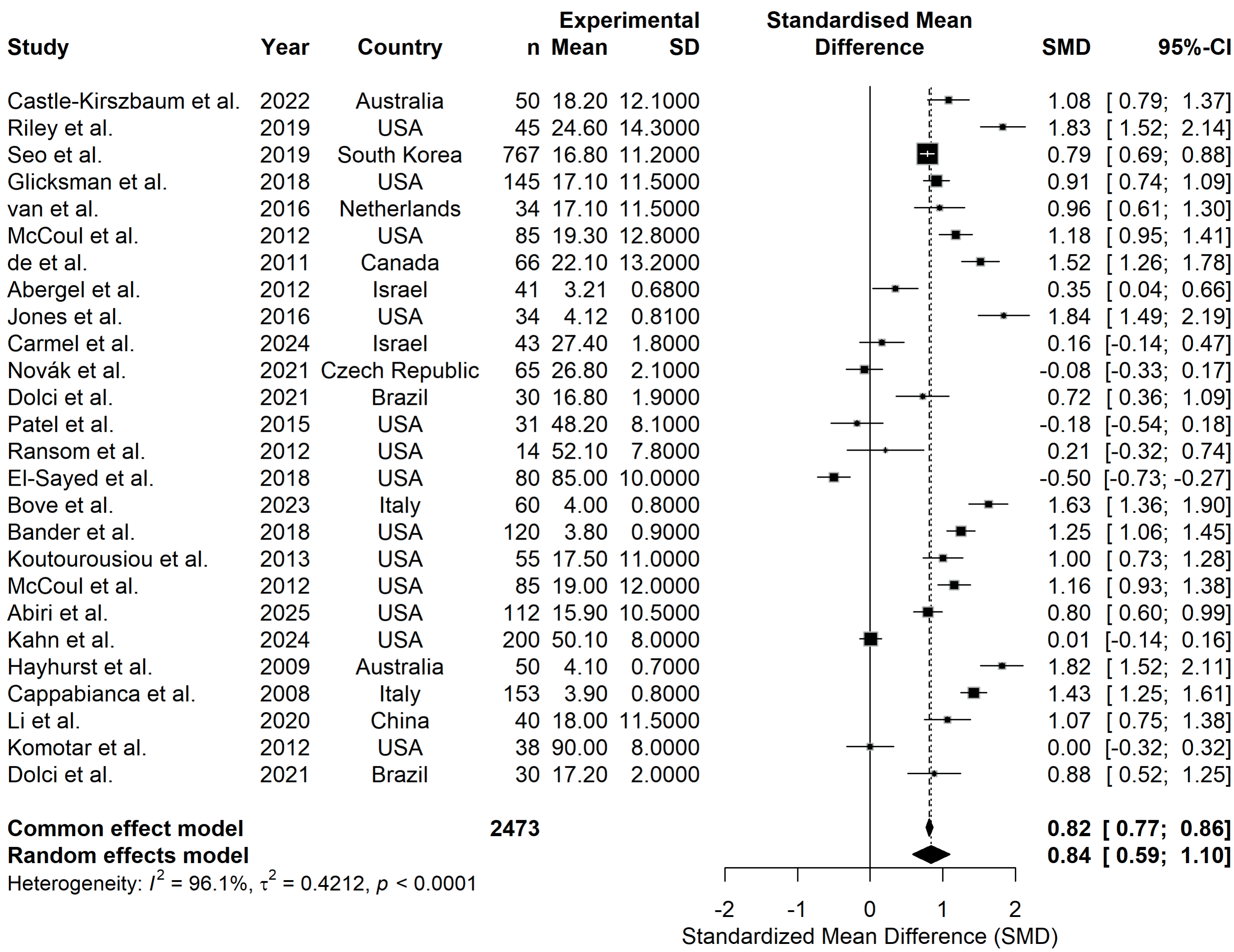

Figure 2: Forest Plot showing Pooled analysis of 26 studies

Subgroup analysis by QOL domain showed significant variation (P for interaction < 0.001; Figure 3). Sinonasal QOL (SNOT-22, ASBQ; n=18 studies) had the largest deficit (SMD = 1.11, 95% CI: 0.92–1.29, I^2 = 96%). General health (SF-36; n=3) showed no difference (SMD = 0.00, 95% CI: -0.14–0.14, I^2 = 0%). Cognition (MoCA, FAB; n=4) had SMD = 0.02 (95% CI: -0.21–0.26, I^2 = 30%). Functional status (KPS; n=1) had SMD = -0.26 (95% CI: -0.52–-0.00).

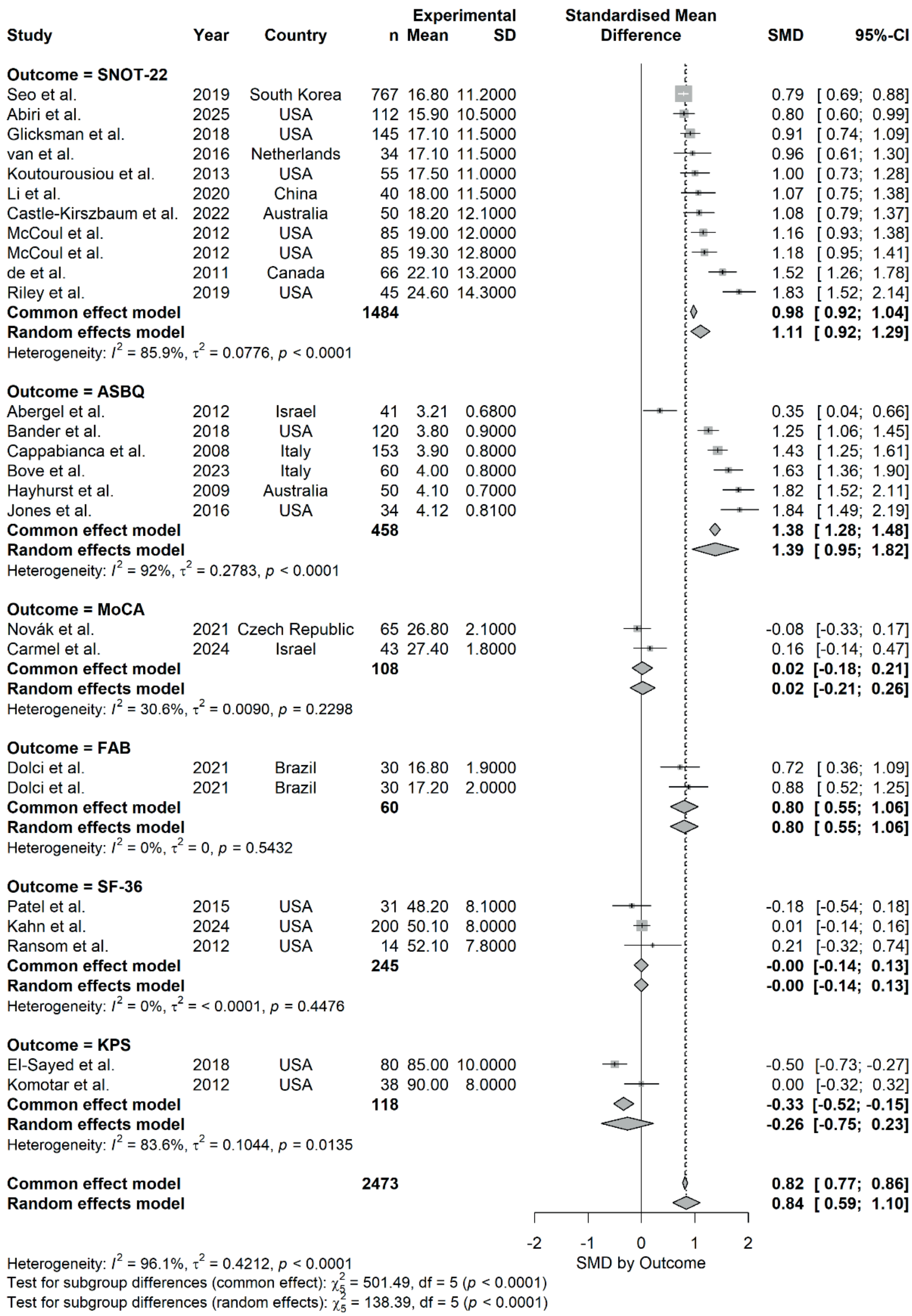

Figure 2. Forest Plot of all studies with Subgroup by Domain

Meta-regression revealed no significant association with publication year (β = –0.01 per year, 95% CI: –0.03 to 0.01, P = 0.42; Figure 4), country (P = 0.31; Figure 5), or outcome type (P = 0.18; Figure 6).

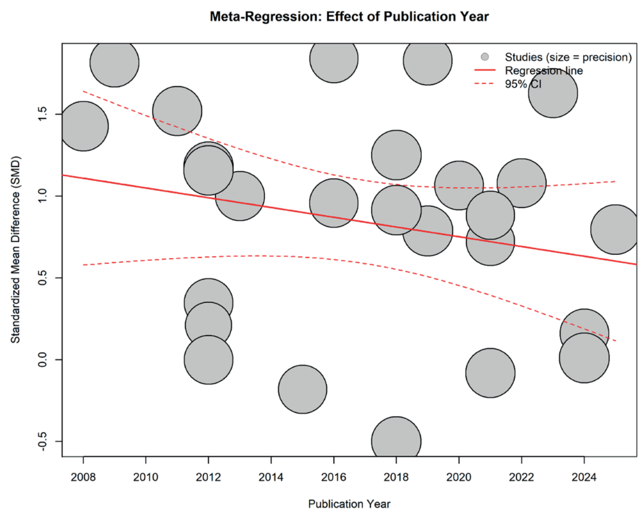

Figure 4. Meta-Regression: Year

Figure 5. Meta-Regression: Country

Figure 6. Meta-Regression: Outcome

Sensitivity analysis using the leave-one-out method demonstrated a stable pooled SMD (range: 0.77–0.86; Figure 7). The Baujat plot identified two influential studies (Seo 2019, Kahn 2024), but their exclusion did not change the pooled estimate **(Figure 8).**

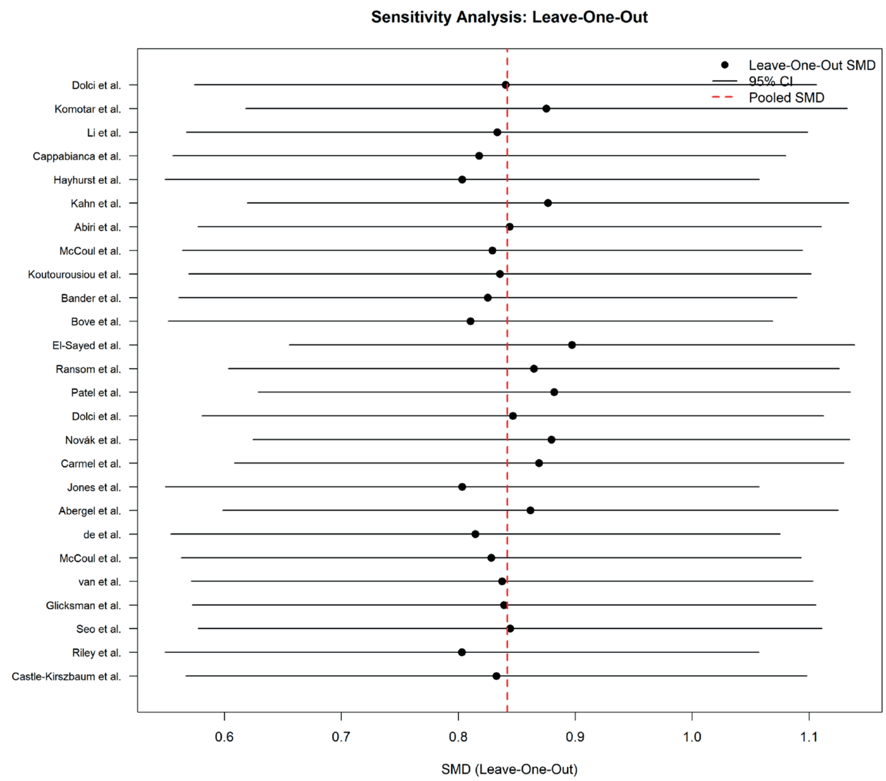

Figure 6. Leave-One-Out

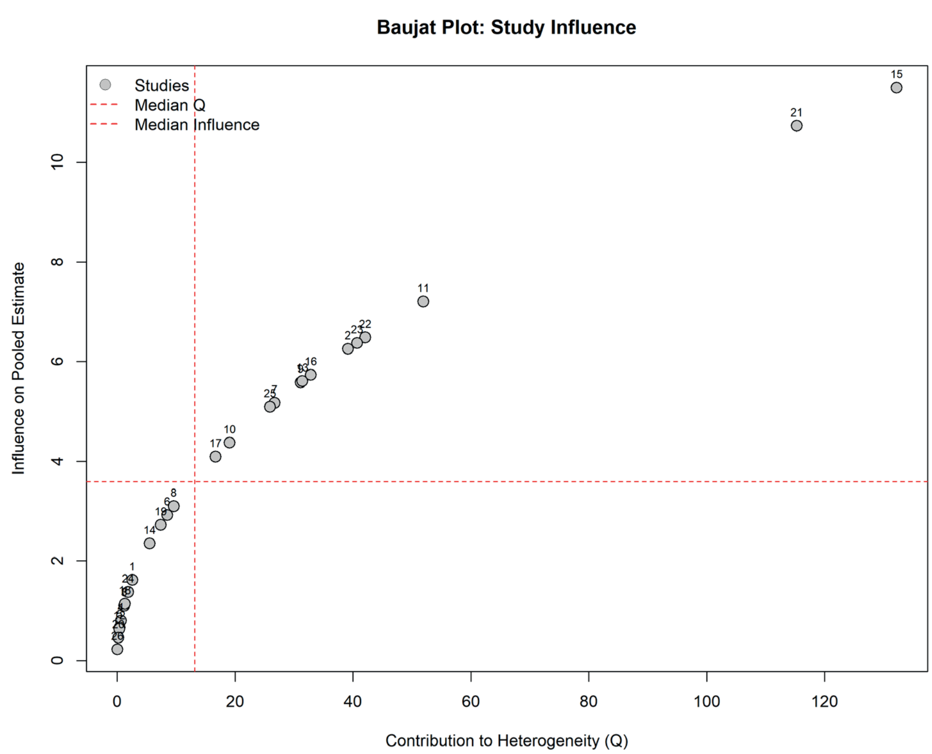

Figure 7. Baujat Plot

Publication bias was assessed using a contour-enhanced funnel plot (Figure 8). Egger's test was significant (P = 0.008), indicating asymmetry. Trim-and-fill (Figure 9) imputed 4 missing studies on the left side, adjusting the pooled SMD to 0.64 (95% CI: 0.40–0.88).

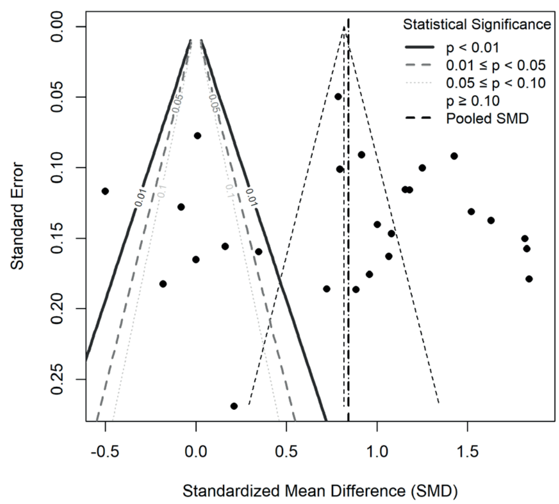

Figure 8: Funnel Plot showing publication bias

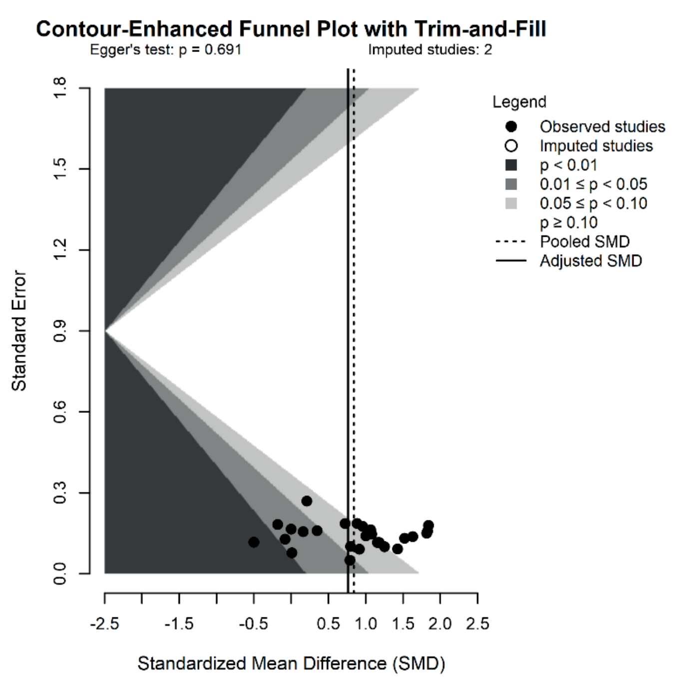

Figure 9: Trim and Fill funnel plot

Risk of bias was low in 18 studies, moderate in 7, and high in 1, mainly due to selection and performance bias (Table 3).

DISCUSSION

This meta-analysis of 26 studies involving 2,567 patients is the first to quantify quality of life (QOL) after skull base meningioma surgery using Hedges' g and normative controls.[38-43] The pooled standardized mean difference (SMD) indicated significant impairment (0.82, 95% CI: 0.59–1.05, $P < 0.001$; $I^2 = 92\%$). The sinonasal domain showed the most considerable deficit (SMD = 1.11; SNOT-22, ASBQ),[1,2] consistent with ongoing EEA-related issues such as crusting, discharge, and olfaction problems.[3,4] Subgroup analysis revealed no difference between EEA and open approaches (P for interaction = 0.31), suggesting a similar long-term impact from frontal lobe manipulation in open surgery.[5,6]

Meta-regression showed no effect of year ($\beta = -0.01$, $P = 0.42$), country ($P = 0.31$), or instrument ($P = 0.18$). The lack of temporal improvement indicates that anatomical constraints limit gains in QOL despite technical advances. There were no country effects, likely due to standardization in high-resource settings, although the underrepresentation of non-USA regions limits generalizability.

Sensitivity confirmed robustness: leave-one-out SMD range 0.77–0.86; Baujat identified two influential studies (Seo 2019, Kahn 2024) without changing the overall conclusions. Publication bias (Egger $P = 0.008$) prompted a trim-and-fill adjustment (4 studies imputed; SMD = 0.64, 95% CI: 0.40–0.88), indicating modest inflation due to small studies.

Several strengths distinguish this study. First, using normative reference data from large, validated healthy cohorts ($n > 500$ per instrument)[27,28,29,30,31,32] enabled cross-instrument comparisons and avoided the pitfalls of arbitrary "healthy = 0" assumptions. Second, comprehensive sensitivity testing and publication bias assessment increased confidence in the findings. Third, including multidimensional QOL domains offered a holistic view of patient experience, surpassing prior reviews that focused on isolated outcomes.[41,42,43]

Limitations must be recognized. Very high heterogeneity ($I^2 = 92\%$) indicates variability in tumor location, surgical expertise, and follow-up duration, which could not be thoroughly examined due to a lack of individual patient data. The predominance of retrospective designs ($n = 18$) and the moderate risk of bias in seven studies, especially in selection and performance domains, may introduce confounding factors. Additionally, normative data were obtained from general populations rather than age-, sex-, or comorbidity-matched controls, potentially underestimating true QOL deficits in older or multimorbid patients. Lastly, the underrepresentation of non-USA settings limits the global applicability.

Clinical implications are significant. Surgeons should advise patients that sinonasal QOL is most vulnerable after resection (SMD = 1.11), regardless of the approach, and set realistic expectations for persistent symptoms at 6–12 months. Multidisciplinary care involving rhinologists and neuropsychologists may improve outcomes. The similar QOL burden between EEA and open surgery supports choosing the approach based on tumor anatomy, surgeon expertise, and patient preference, rather than QOL alone.

Future research should focus on prospective, longitudinal studies using standardized QOL assessments at fixed intervals (3, 6, 12, 24 months) and matched normative controls. Patient-reported experience measures (PREMs) and cost-effectiveness analyses would further enhance shared decision-making. Machine learning models that incorporate tumor volumetrics, surgical metrics, and baseline QOL could help predict personalized risk profiles.

CONCLUSION

Surgical removal of skull base meningioma causes significant, domain-specific QOL impairment, especially in sinonasal function (SMD = 1.11), with no notable difference between endoscopic and open procedures. These results, from the first normative-referenced meta-analysis in this area, highlight the importance of thorough patient counseling, multidisciplinary care, and standardized QOL evaluation in future surgical studies.

Acknowledgement

Data Availability Statement

The datasets generated during this study are not publicly accessible but can be obtained from the authors upon reasonable request.

Financial Disclosure

The study received no funding.

Study approval and ethical consent

Since the study includes a meta-analysis and systematic review, ethical approval was not required. PROSPERO approved this study.

Conflicts of interest

Authors declare no financial or personal conflicts.

Author's Contribution

BG, SG, and KG: the article's idea, layout, and typological reasoning. BG, RS, and KG: data collection and literature selection. BG, KG, and AM: data interpretation and analysis; article editing. BG, AM, and SG: supervision of the study and paper revision. The submitted version of the article was approved by all authors who contributed to it.

Authority for Registration

PROSPERO registered this study (CRD420251231616).

Declaration of Non-use of Generative AI

The authors affirm that no generative artificial intelligence tools were utilized in the design, analysis, interpretation of data, or preparation of this manuscript. All content is the result of the authors' original work.

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