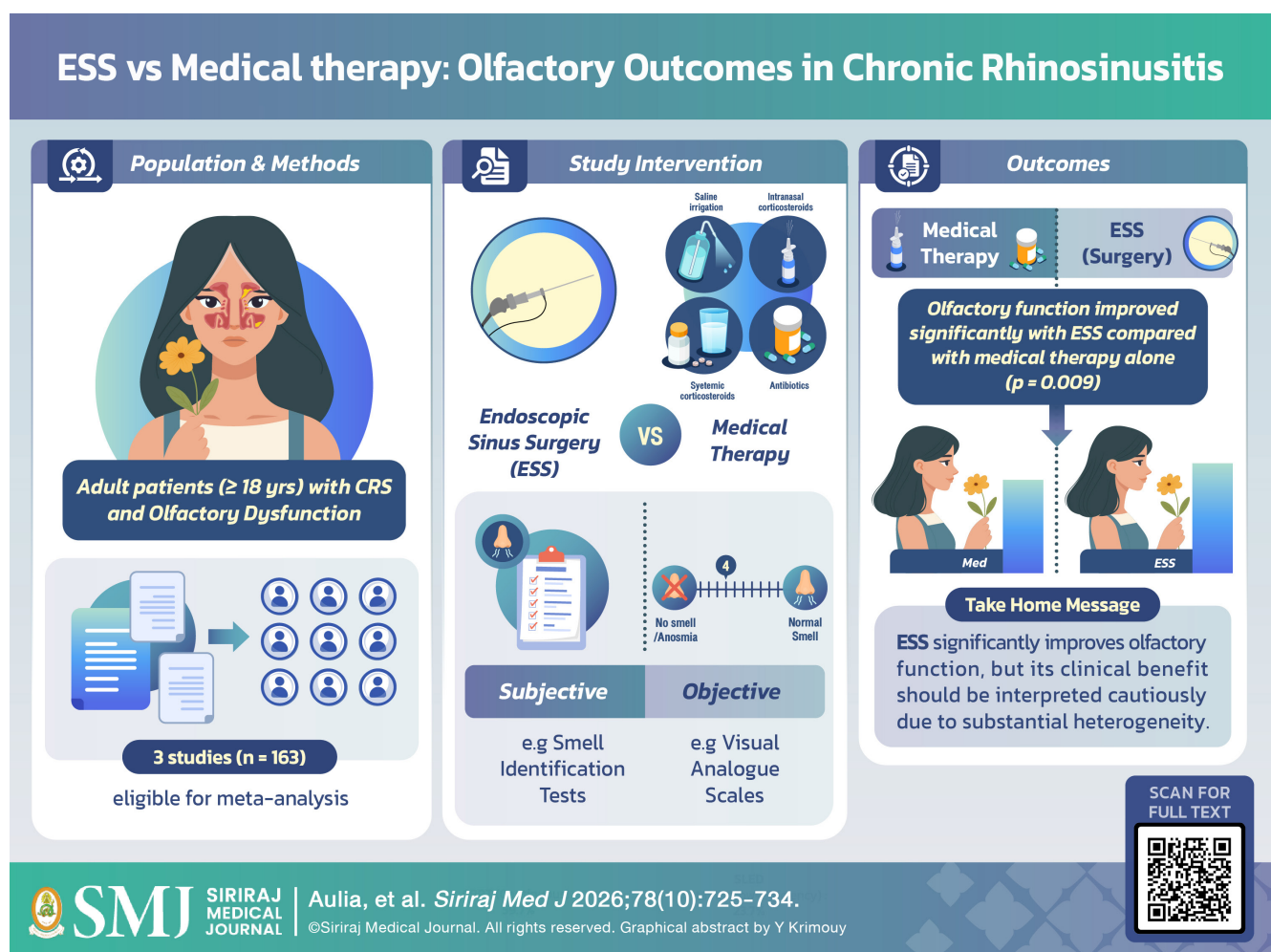


Comparative Effectiveness of Endoscopic Sinus Surgery Versus Medical Therapy on Olfactory Function in Chronic Rhinosinusitis: A Systematic Review and Meta-Analysis

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ABSTRACT

Objective: This study aimed to compare the effectiveness of ESS versus medical therapy in improving olfactory function among adult patients with CRS.

Materials and Methods: A systematic review and meta-analysis were conducted using PubMed, Cochrane Library, and ScienceDirect. Comparative studies evaluating ESS and medical therapy with reported olfactory outcomes were included. Standardized mean differences (SMD) were calculated using a random-effects model. Outcomes were oriented such that higher values indicated better olfactory function.

Results: Four studies were included in the qualitative synthesis, with three studies (n = 163) eligible for quantitative meta-analysis. The pooled analysis demonstrated a statistically significant improvement favoring ESS over medical therapy alone (SMD = 1.02, 95% CI: 0.26 to 1.78; p = 0.009), though substantial statistical heterogeneity was observed ($I^2 = 75\%$). Individual studies showed variable results across outcome metrics. Despite this statistical difference, the comparative clinical efficacy remains highly uncertain due to high risk of bias, small study numbers, and differences between objective psychophysical testing and subjective self-reported measures.

Conclusion: Evidence regarding the comparative effectiveness of ESS versus medical therapy in improving olfactory function remains highly uncertain. Given the methodological limitations of current data, further high-quality, well-phenotyped trials are required to clarify relative treatment efficacy.

Keywords: Chronic rhinosinusitis; endoscopic sinus surgery; medical therapy; olfactory dysfunction; meta-analysis (Siriraj Med J 2026;78(10):725-734)

INTRODUCTION

Chronic rhinosinusitis (CRS) is a heterogeneous inflammatory disease affecting 5% to 12% of the global population.¹⁻³ While its classical symptoms include mucopurulent discharge, nasal obstruction and facial pressure, olfactory dysfunction has increasingly been recognized as one of its most distressing and impactful manifestations.^{2,4}

Olfactory impairment in CRS represents a critical determinant of patient-reported outcomes. Loss or reduction of smell has been consistently associated with diminished quality of life, impaired taste, reduced appetite, and heightened safety risks from environmental hazards.⁴⁻⁶ As such, restoration of olfactory function has emerged as a central therapeutic objective alongside the control of inflammation and sinonasal symptoms.

The underlying mechanisms of olfactory loss in CRS involve both conductive and sensorineural components. Conductive impairment arises from physical obstruction of the olfactory cleft by mucosal edema, polyps, or secretions, limiting odorant access to the epithelium.^{5,7,8} In parallel, chronic type 2 inflammation driven by eosinophilic infiltration and cytokine dysregulation can directly damage the neuroepithelium, leading to persistent or irreversible dysfunction.^{8,9} These mechanisms are prominent in CRSwNP, where olfactory loss is typically more severe and treatment resistant.^{8,9} Consequently, effective management requires therapeutic strategies

that address both structural obstruction and underlying inflammatory pathways.

Current CRS management follows a stepwise approach, beginning with maximal medical therapy including intranasal corticosteroids and saline irrigation, and, when indicated, short courses of systemic corticosteroids or antibiotics.^{2,3} While effective in controlling general disease activity by reducing inflammation and improving sinonasal patency, its impact on olfactory recovery is still unpredictable and often suboptimal, particularly in patients with longstanding disease or extensive polyp burden.^{6,10} Improvements in olfaction are transient and may diminish after cessation of systemic therapy, highlighting the limitations of medical management alone.^{6,10}

For patients with refractory CRS, endoscopic sinus surgery (ESS) is commonly considered as the next line of treatment. ESS restores sinus ventilation and drainage by removing obstructive tissue, enlarging sinus ostia, and enhancing the penetration of topical therapies to the sinonasal mucosa, potentially improving long-term disease control.^{1,3} From a mechanistic perspective, ESS may offer advantages in restoring olfactory function by addressing both conductive barriers and reducing inflammatory load within the olfactory cleft.^{6,7} Nevertheless, the extent to which these theoretical benefits translate into meaningful clinical improvement in olfaction remains a matter of ongoing discussion.

Existing literature comparing the effectiveness

of ESS and continued medical therapy in improving olfactory outcomes has yielded inconsistent findings. Some studies suggest that surgical intervention results in greater improvement in olfactory function, particularly in CRSwNP patients or severe baseline impairment.^{6,7} Conversely, other studies reported comparable results, especially when using objective measures.^{4,10} These discrepancies may be explained by variations in study design, patient selection, baseline disease severity, and the type of outcome measures used. Indeed, heterogeneity in olfactory assessment tools, ranging from objective tests such as the Brief Smell Identification Test (B-SIT) and Sniffin' Sticks to subjective patient-reported scales, challenges the synthesis of evidence across studies.^{4,5}

Furthermore, recent advances in CRS endotypes and the emergence of targeted biologic therapies have complicated the treatment landscape, particularly for CRSwNP.⁸ Although biologics demonstrate promising results in improving olfactory function, their high cost and limited accessibility necessitate continued evaluation of conventional modalities like ESS and medical therapy.^{8,9} Therefore, clarifying the comparative effectiveness of these established interventions remains highly relevant, especially in resource-limited settings.

However, given the critical role of olfactory function in overall disease burden, a comprehensive synthesis of evidence is warranted to address outcome measurement variability. Therefore, this systematic review and meta-analysis aims to evaluate and compare the effectiveness of endoscopic sinus surgery versus medical therapy in improving olfactory function among adult populations diagnosed with chronic rhinosinusitis.

MATERIALS AND METHODS

Study design

This study was designed as a systematic review and meta-analysis to evaluate the comparative effectiveness of endoscopic sinus surgery (ESS) versus medical therapy in improving olfactory function among adult patients with chronic rhinosinusitis (CRS). This study was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. A protocol was not prospectively registered for this review.

Eligibility criteria

Study selection was performed using predefined inclusion and exclusion criteria based on the Population, Intervention, Comparator, and Outcomes (PICO) framework.

Studies were selected based on the PICOS framework.

We included studies evaluating adult patients (≥ 18 years) diagnosed with chronic rhinosinusitis (CRS), with or without nasal polyps, according to the EPOS 2020 diagnostic criteria. Eligible studies compared endoscopic sinus surgery (ESS) with medical therapy consisting of intranasal/systemic corticosteroids and/or nasal saline irrigations for a minimum of 4 weeks.

Outcomes of interest were olfactory function changes evaluated using validated objective instruments (smell identification tests) or subjective assessment tools (Visual Analog Scale). Studies required a minimum follow-up duration of 3 months post-treatment. When outcomes were reported at multiple post-treatment time points, data from the primary reported endpoint or the longest follow-up time point closest to 12 months were selected for quantitative synthesis.

Only full-text, peer-reviewed comparative studies published in English were included. Case reports, editorials, conference abstracts, pediatric studies (< 18 years), and studies with non-extractable outcome data were excluded.

The intervention of interest was endoscopic sinus surgery (ESS) followed by standard postoperative medical therapy, reflecting a treatment strategy of surgery with postoperative medical management. The comparator was continued medical therapy without surgery, with regimens varying across studies and including saline irrigation, intranasal corticosteroids, systemic corticosteroids, and/or antibiotics. Accordingly, the target estimand was the comparative effect of an ESS-based treatment strategy (ESS plus postoperative medical therapy) versus continued medical therapy alone, rather than the isolated effect of surgery itself.

The primary outcome was improvement in olfactory function, assessed using either objective measures (e.g., smell identification tests) or subjective patient-reported outcomes (e.g., visual analogue scales). Studies that did not report olfactory outcomes separately or did not report adequate data for quantitative extraction were excluded from the meta-analysis and instead considered for qualitative synthesis.

Furthermore, eligible study designs included randomized controlled trials and observational comparative studies. Case reports, case series without comparator groups, editorials, review articles, and conference abstracts were excluded from analysis.

Information sources and search strategy

A comprehensive literature search was conducted across three electronic databases (PubMed, Cochrane Library, and ScienceDirect) from inception to April 4, 2026. The strategy combined MeSH terms and free-

text keywords covering three main domains: chronic rhinosinusitis, endoscopic sinus surgery versus medical therapy, and olfactory function. In accordance with PRISMA 2020 and PRISMA-S guidelines, the complete, line-by-line search strategies for each database including exact field tags, Boolean operators, and applied filters are provided in [Supplementary Material 1](#).

The search strategy targeted comparative studies evaluating ESS and medical therapy for olfactory outcomes in CRS. To complement database searching, reference lists of included articles and relevant systematic reviews were manually screened to identify additional studies. Primary database selection was limited to PubMed, Cochrane Library, and ScienceDirect based on institutional accessibility. Across all databases, the search yielded a total of 828 records.

Study selection

Record screening and selection were conducted independently and in duplicate by the two authors at both the title/abstract and full-text evaluation stages. Reference management, deduplication, and title/abstract screening were performed using Microsoft Excel. Full-text articles of potentially eligible studies were retrieved and independently assessed against the predefined inclusion criteria. Disagreements between the two reviewers were resolved through structured re-evaluation of the study data against the eligibility criteria and joint discussion until full consensus was achieved.

The duplicate records were identified and removed before the full-text screening. The disagreements in study selection were resolved through discussion and consensus. The complete study selection process is presented in the PRISMA flow diagram.

Data extraction

Data were extracted independently in duplicate by both authors using a standardized form. Variables extracted included study characteristics, demographics, CRS subtypes, intervention protocols, olfactory instruments, follow-up durations, and quantitative outcomes (means, SDs, sample sizes). Study characteristics and qualitative findings are summarized in [Table 1](#). The complete extraction form and raw quantitative dataset used for meta-analysis are provided in [Fig 2](#). Disagreements were resolved by consensus, and primary authors were contacted via email for missing data.

Continuous outcome data reported as medians and interquartile ranges (Zhang et al., 2024) were transformed into estimated means and standard deviations using validated statistical formulas. No standard deviations

were borrowed or imputed across studies. Detailed transformation parameters for each study are provided in [Supplementary Material 2](#). To test the robustness of the primary findings, a sensitivity analysis was performed by excluding transformed data (Zhang et al., 2024) and retaining only studies with directly reported mean and standard deviation values (Smith et al., 2011; DeConde et al., 2014).

Risk of bias assessment

Risk of bias was evaluated independently in duplicate by both authors using RoB 2 for the randomized trial (Ragab et al., 2004) and ROBINS-I for non-randomized cohort studies (Smith et al., 2011; DeConde et al., 2014; Zhang et al., 2024). Disagreements were resolved by consensus. The RCT was judged as having “some concerns” (due to unblinded outcome assessment), while non-randomized studies were categorized as “moderate risk of bias” (due to potential selection bias and confounding). Detailed domain-level evaluations and justifications are provided in [Supplementary Material 3](#).

Statistical analysis

To address construct heterogeneity among outcome measures, continuous olfactory data were synthesized separately. Outcome instruments were categorized into objective psychophysical olfactory tests and subjective patient-reported olfactory outcomes. Standardized mean differences (SMDs) with 95% confidence intervals were calculated separately within each construct subgroup using random-effects models. Pooling across non-equivalent constructs was strictly avoided.

All of the outcomes were oriented so that higher values indicated better olfactory function. For studies in which higher scores represented worse symptoms, values were reversed before the analysis.

Quantitative synthesis used inverse-variance random-effects models with DerSimonian–Laird variance estimation (τ^2) and Hedges’ g correction for small-sample bias. Heterogeneity was assessed using I^2 (>50% indicating substantial heterogeneity). Given $k=3$, Knapp–Hartung adjustments and fixed-effects sensitivity analyses were applied to verify stability, with results interpreted cautiously. Prediction intervals were omitted due to $k < 10$.

All analyses were conducted using Review Manager (RevMan, version 5.4.1), with statistical significance set at $p < 0.05$. The primary synthesis evaluated olfactory outcomes at the 6-month follow-up (range: 3–12 months). Post-treatment endpoint scores (mean $\pm$ SD) were defined as the primary input data; where change scores were reported, endpoint values were reconstructed per

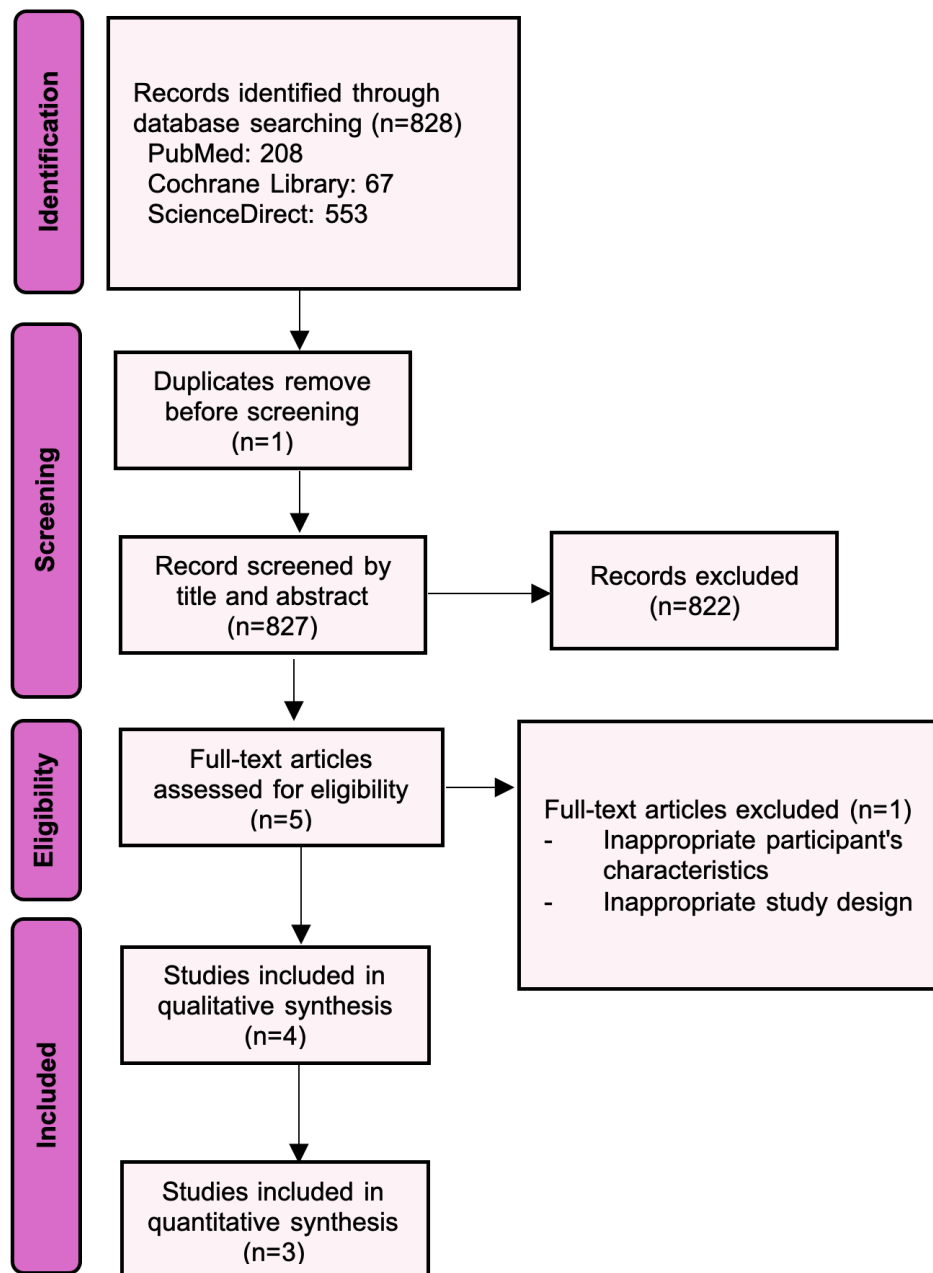


Fig 1. Diagram flow of literature search strategy for this systematic review.

Quantitative Synthesis (Meta-analysis of Olfactory Outcomes)

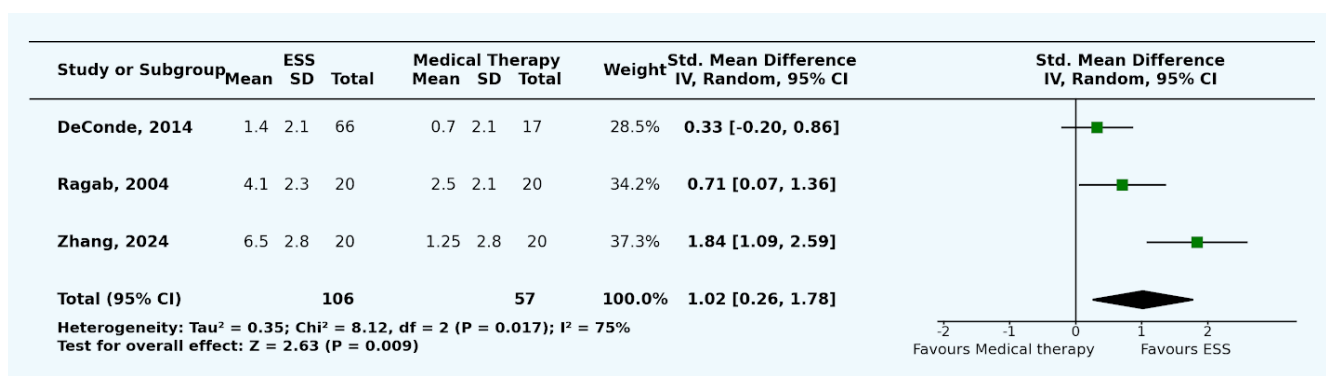


Fig 2. Pooled result for olfactory outcome.

TABLE 1. Characteristics and results of the included studies.

First Author (Year)	Country / Setting	Study Design	Population (Inclusion Criteria)	Sample Size (ESS / Medical)	Mean Age (ESS / Medical)	Male (%)	CRS Type (CRSwNP / CRSsNP)	Baseline Olfactory Status	Intervention Details (ESS + postop therapy)	Comparator (Medical Therapy)	Olfactory Measurement Tool	Follow-up Duration	Key Results	Summary of Findings	Risk of Bias
Smith et al. (2011) ¹¹	USA (multi-institutional: OHSU, NWU, MUSC, UPenn)	Prospective non-randomized cohort	Adults ≥18 years with CRS who failed initial medical therapy	75 / 55 (analyzed at 6 months)	44.1 / 51.5	52.5% / 43.2%	Mixed CRS (polyps present ~39% ESS vs 33% medical)	Not reported	ESS + continued medical therapy based on clinician judgment	Continued medical therapy (antibiotics, steroids, etc.)	Not reported (QOL-based: RSDI, CSS)	6 months	ESS showed significantly greater improvement in QOL (RSDI, CSS) and reduced antibiotic/steroid use and missed days	ESS superior to medical therapy in improving disease-specific outcomes	Low
Zhang et al. (2024) ¹²	China (single-center, Beijing Tongren Hospital)	Prospective cohort	Adults with CRSwNP nonresponsive to intranasal corticosteroids	20 / 20	43.6 / 42.2	50% / 60%	CRSwNP only	Worse in steroid group (VAS olfactory median 9.90 vs 9.30, p=0.0225)	ESS + postoperative intranasal corticosteroids	Oral corticosteroids (methylprednisolone taper) + intranasal steroids	VAS (olfactory function, 0–10 scale)	3 months	Both groups improved, but ESS showed significantly greater improvement in olfactory function	ESS provides superior olfactory improvement vs oral corticosteroids	Low
DeConde et al. (2014) ¹³	USA (multi-institutional: Oregon, South Carolina, Stanford)	Prospective cohort (non-randomized)	Adult CRS patients refractory to initial medical therapy	222 / 58 (total analyzed n=280)	51.9 vs 50.3	53.6% vs 39.7%	CRSwNP + CRSsNP	29.6% impaired olfaction at baseline	ESS + postoperative medical therapy	Continued medical therapy (antibiotics, steroids)	B-SIT (0–12)	≥6 months (mean ~ 12 months)	Both groups improved B-SIT significantly; no difference between groups	ESS and medical therapy yield comparable olfactory improvement	Low
Ragab et al. (2004) ¹⁴	UK (Royal National Throat, Nose and Ear Hospital, London)	Randomized Controlled Trial	Adults with CRS refractory to initial medical therapy (≥8 weeks symptoms + CT changes)	45 / 45 (total n=90)	43 ± 13	50% male	CRSwNP + CRSsNP	Included (olfactory disturbance part of VAS)	ESS + postoperative medical therapy (macrolide, steroid, douche)	Continued medical therapy (erythromycin + steroid + douche)	VAS (subjective; includes olfactory domain)	6 months & 12 months	Significant improvement in both groups; no significant difference between ESS and medical therapy	ESS and medical therapy show comparable improvement in CRS outcomes including olfactory symptoms	Low

Cochrane guidelines. To prevent multiplicity bias, only one primary olfactory scale was extracted per study. Full input data and exact parameters are documented in Fig 2 for complete plot reproducibility.

RESULTS

Study selection

A total of 828 records were identified through database searches (PubMed: 208; Cochrane Library: 67; ScienceDirect: 553). Prior to screening, 1 duplicate record was removed, leaving 827 unique records for screening. Title and abstract screening resulted in the exclusion of 822 records due to irrelevance to the study question. Five full-text articles were sought and retrieved for full eligibility assessment. One full-text article was excluded due to inappropriate participant characteristics and non-eligible study design. Ultimately, four studies were included in the qualitative synthesis. Of these, three studies provided isolated, quantitative olfactory outcome data and were included in the quantitative meta-analysis.

Study characteristics

The four included studies consisted of one randomized controlled trial and three prospective cohort studies, encompassing adult patients with chronic rhinosinusitis (CRS), with or without nasal polyps. Sample sizes varied across studies, with the largest cohort reported by DeConde et al. (2014), while Zhang et al. (2024) included the smallest sample.^{12,13} Interventions consisted of endoscopic sinus surgery (ESS) followed by standard postoperative medical therapy, compared with continued medical therapy alone, which typically included corticosteroids and/or antibiotics.

Eligibility was strictly limited to studies reporting isolated olfactory outcomes. DeConde et al. (2014) provided objective psychophysical data (B-SIT),¹³ while Ragab et al. (2004) and Zhang et al. (2024) provided subjective olfactory ratings (VAS).^{12,14} Smith et al. (2011) was excluded from quantitative synthesis due to a lack of discrete olfactory endpoints. For Zhang et al. (2024), continuous data presented as medians and IQRs were converted to means and SDs using validated transformation formulas per Cochrane guidelines. To address potential selection bias and transformation uncertainty in Zhang et al., an exclusion sensitivity analysis was performed.

Following a comprehensive data audit against the primary reports, three studies were included in the quantitative meta-analysis, evaluating a reconciled total of 163 participants (ESS group vs. medical therapy group). DeConde et al. (2014) contributed objective

B-SIT outcomes from the olfaction-impaired cohort ($n = 66$ ESS, $n = 17$ Medical). Subjective olfactory outcomes (VAS) were contributed by Ragab et al. (2004) ($n = 20$ ESS, $n = 20$ Medical) and Zhang et al. (2024) ($n = 20$ ESS, $n = 20$ Medical). Smith et al. (2011) was excluded from quantitative olfactory synthesis due to the absence of an isolated olfactory endpoint.

The pooled random-effects estimate yielded a standardized mean difference (SMD) of 1.02 (95% CI: 0.26 to 1.78; $Z = 2.63$, $p = 0.009$). Patients receiving endoscopic sinus surgery (ESS) demonstrated higher olfactory improvement scores compared to those receiving medical therapy alone. Substantial statistical heterogeneity was observed across studies ($I^2 = 75\%$, $p = 0.017$).

Individually, Zhang et al. (2024) reported a substantial improvement favoring ESS (SMD = 1.84; 95% CI: 1.09 to 2.59), and Ragab et al. (2004) similarly demonstrated a significant benefit in subjective olfactory VAS scores favoring ESS over medical therapy (SMD = 0.71; 95% CI: 0.07 to 1.36). In contrast, DeConde et al. (2014) showed a positive direction of effect favoring ESS in the olfaction-impaired subgroup, though this difference did not reach statistical significance (SMD = 0.33; 95% CI: -0.20 to 0.86).

Heterogeneity and consistency

Considerable statistical heterogeneity was identified across the included studies ($I^2 = 75\%$, $\tau^2 = 0.35$, $P = 0.01$). Given the small number of pooled studies ($k = 3$), empirical meta-regression or subgroup analyses to establish the exact sources of heterogeneity were not feasible. Methodologically, this variability may reflect differences in outcome measurement instruments (objective psychophysical testing vs. subjective VAS), patient clinical profiles (CRSwNP vs. mixed CRS populations), and study designs. Due to the limited number of studies ($k = 3$), a formal 95% prediction interval could not be reliably calculated, as variance estimators for between-study variance are highly unstable with fewer than four studies.

Overall interpretation of findings

While individual studies demonstrated variable degrees of olfactory recovery, the pooled quantitative synthesis indicated that endoscopic sinus surgery (ESS) yields a statistically significant improvement in olfactory function compared with medical therapy alone. However, the substantial statistical heterogeneity reflects notable methodological variability in outcome instruments and patient characteristics across the included trials.

Thus, these findings suggest that while ESS may offer potentially important improvements in selected patients,

particularly those with more severe or refractory disease, its overall advantage in restoring olfactory function compared with medical therapy alone demonstrates a large statistical effect size. However, because included studies utilized heterogeneous outcome tools without a standardized anchor-based minimally important difference (MID), the precise clinical magnitude of this improvement warrants cautious interpretation.

DISCUSSION

Principal findings

The pooled quantitative analysis demonstrated that ESS provides a statistically significant improvement in olfactory outcomes compared with medical therapy alone. These findings suggest that ESS offers potentially important benefits in restoring olfactory function, though substantial clinical and methodological heterogeneity across studies warrants cautious interpretation.

This observation was particularly relevant when considered alongside the current understanding of CRS as a multifactorial inflammatory disease. While ESS effectively restored sinus ventilation and removed obstructive tissue, olfactory recovery is not solely dependent on anatomical factors but is also strongly influenced by persistent mucosal inflammation and potential damage to the olfactory neuroepithelium.^{2,6,15} Therefore, the statistically significant superiority of ESS over medical therapy may reflect the synergistic impact of combining structural clearance with ongoing inflammatory control in reversing olfactory dysfunction.

Comparison with existing literature

The findings of this study were consistent with previous evidence indicating that both surgical and medical interventions can lead to meaningful improvements in CRS-related symptoms, including olfactory dysfunction.^{1,3} Several studies have shown that corticosteroid-based medical therapy can significantly improve olfactory outcomes, particularly in patients with type 2 inflammatory endotypes, thereby narrowing the expected advantage of surgical intervention.^{5,16}

Conversely, other reports suggested that ESS may offer superior improvement in olfaction, especially in patients with nasal polyps or more severe baseline impairment.^{4,5} This apparent inconsistency across studies may be attributed to variations in the study populations, baseline disease severity, and outcome measurement methods. Importantly, patients selected for surgery are often those with refractory disease, which may predispose them to greater relative improvement compared to those managed medically.¹⁶

Objective versus subjective olfactory outcomes

A key finding in this analysis was the divergence between objective and subjective measures of olfactory function. Studies employing objective assessments, such as smell identification tests, generally showed comparable outcomes between ESS and medical therapy. In contrast, subjective measures, including visual analogue scales, more frequently indicated greater improvement following surgical intervention.

This discrepancy may be explained by the influence of overall symptom relief on patient perception. Improvement in nasal airflow and reduction of obstruction following ESS may enhance the subjective experience of smell without corresponding changes in measurable olfactory performance.⁴ Additionally, objective tests may not fully capture subtle functional improvements or the multidimensional nature of olfactory perception.⁷ These findings highlighted the importance of integrating both objective and patient-reported outcomes in future studies.

Role of CRS phenotype and inflammation

The heterogeneity observed in treatment response was likely influenced by differences in CRS phenotype and underlying inflammatory pathways. CRSwNP, characterized by type 2 inflammation and eosinophilic predominance, is associated with more severe olfactory dysfunction and may respond differently to treatment modalities.^{1,3}

While ESS can effectively reduce polyp burden and improve airflow, persistent inflammation may limit long-term recovery of olfactory function.¹⁷ In recalcitrant CRS, osteitis represents a key hallmark of persistent mucosal inflammation and tissue remodeling, which is associated with severe disease states and reduced responsiveness to standard therapies.¹⁸ In contrast, medical therapies, particularly corticosteroids and emerging biologic agents, target inflammatory pathways more directly and may play a critical role in restoring olfactory function at the cellular level.^{3,15} This supports the concept that optimal management of CRS requires a combined approach addressing both structural and inflammatory components.^{1,10,15–17}

Clinical implications

From a clinical standpoint, these findings suggest that ESS should not be universally regarded as superior to medical therapy for the improvement of olfactory function alone. Instead, treatment decisions should be individualized based on disease severity, phenotype, prior response to therapy, and patient preferences.^{6,8}

Medical therapy remains a fundamental component

of chronic rhinosinusitis (CRS) management and may be sufficient to achieve meaningful olfactory improvement in selected patients.^{6,8} ESS continues to be an important option for patients with refractory disease or significant anatomical obstruction; however, clinicians should provide realistic expectations regarding the extent of olfactory recovery following surgery.^{2,10}

Limitations

Several critical limitations must be considered when interpreting these findings. First, the small number of included studies ($k = 3$) limits statistical power and precision, yielding a very low overall certainty of evidence. Second, substantial heterogeneity ($I^2 = 75\%$) was identified, driven by combining distinct outcome constructs namely objective psychophysical tests and subjective self-reported measures alongside variations in CRS subtypes and baseline disease severity. Third, methodological constraints in primary studies introduce potential risk of bias, including non-randomized treatment selection, unexplained subgroup sample sizes, imputed standard deviations for incomplete statistical reporting, and potential selective outcome inclusion. Finally, the absence of a pre-registered review protocol limits methodological transparency.

Future directions

Future research should prioritize well-designed randomized controlled trials with standardized olfactory outcome measures to improve comparability across studies. The use of validated objective tools combined with patient-reported outcomes will be essential to provide a comprehensive assessment of treatment effects.⁷

Additionally, further investigation into the role of CRS phenotypes and inflammatory endotypes in predicting treatment response is warranted. Emerging therapies targeting specific inflammatory pathways, including biologic agents, may offer new opportunities for improving olfactory outcomes and should be explored in future comparative studies.^{15,16,19,20}

CONCLUSIONS

Current evidence regarding the comparative effectiveness of endoscopic sinus surgery (ESS) versus medical therapy for olfactory restoration in chronic rhinosinusitis remains highly uncertain. Although the pooled quantitative synthesis indicated a statistically significant improvement favoring ESS, this finding is limited by substantial statistical heterogeneity, a small number of included studies, wide confidence intervals, and a high risk of methodological bias. Consequently,

no definitive clinical practice recommendations can be made from this analysis. Well-designed, randomized controlled trials employing standardized, objective olfactory assessments are needed to establish the true comparative efficacy of these interventions.

Data Availability Statement

No primary data were generated for this study. This systematic review and meta-analysis were conducted using secondary data extracted from previously published studies. All studies included in the analysis are cited in the reference list.

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DECLARATIONS

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Conflict of Interest

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Registration Number of Clinical Trial

Not applicable. This manuscript is a systematic review and meta-analysis, not a primary clinical trial.

Author Contributions

Conceptualization and methodology, N.A.A and W.I.A.S; Formal analysis, N.A.A and W.I.A.S; Visualization and writing – original draft, N.A.A ; Writing – review and editing, N.A.A and W.I.A.S. All authors have read and agreed to the final version of the manuscript.

Use of Artificial Intelligence

During the preparation of this manuscript, the authors used Grammarly solely for language editing, grammar correction, and improving structural readability. No artificial intelligence tools were used in the conception, database literature search (PubMed, Cochrane Library, ScienceDirect), screening, data extraction, risk of bias assessment, or statistical meta-analysis conducted via RevMan 5.4.1. The authors reviewed and edited the final manuscript and take full responsibility for the content of this publication.

Institutional Review Board Statement

Ethical approval was not required for this study, as it is a systematic review and meta-analysis based entirely on previously published literature and does not involve direct human subjects or biological samples.

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