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Temporomandibular Joint Disorders - An Evidence-Based Systematic Review and Meta-Analysis Comparing Surgical and Non-Surgical Management Strategies

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Abstract

Background: Temporomandibular disorders (TMD) represent a heterogeneous cluster of musculoskeletal and neuromuscular conditions involving the temporo mandibular joint (TMJ), masticatory muscles, and associated structures. They are among the most prevalent orofacial pain conditions, affecting approximately 5–12% of the global population[1]. Despite decades of research, the optimal management pathway – non - surgical or surgical - remains debated, with treatment selection often driven by clinician preference rather than stratified evidence.

Objectives: To systematically compare the efficacy, safety, and long-term outcomes of surgical interventions (arthrocentesis, arthroscopy, open joint surgery, total joint replacement) versus non-surgical interventions (occlusal splint therapy, physical therapy, pharma co therapy, cognitive - behavioral therapy) for TMD, and to derive pooled effect estimates through meta-analysis.

Methods: A systematic search of Pub Med, Cochrane Library, Scopus, and Embase (1995–2024) was conducted following PRISMA 2020 guidelines. Studies reporting pain (VAS), maximum mouth opening (MMO), or jaw function in adults with confirmed TMD were eligible. Quality assessment used Cochrane RoB 2 for RCTs and the Newcastle-Ottawa Scale for observational studies. Meta-analysis used random-effects models (Der Simoni an-Laird). Heterogeneity was quantified by I^2. Subgroup analyses were performed by TMD severity (Wilkes classification) and follow-up duration.

Results: 69 studies (n=12,847 patients) met inclusion criteria; 38 contributed to meta-analysis. Surgical interventions produced significantly greater improve ments in pain (pooled SMD 0.61; 95% CI 0.49–0.74; I^2 = 42.3 %; $p<0.001$) and MMO (pooled SMD 0.82; 95% CI 0.67 – 0.97; I^2 = 38.7%; $p <0.001$) versus non-surgical comparators. However, complication rates were significantly higher with surgery (OR 2.87; 95% CI 1.94 – 4.24). Subgroup analysis demonstrated near-equivalent

outcomes between surgical and non-surgical approaches for mild TMD (Wilkes I–II), while surgical superiority was pronounced for severe disease (Wilkes IV–V; SMD 1.18). Recurrence rates did not differ significantly (OR 0.68; 95% CI 0.44–1.05; p=0.079).

Conclusions: Evidence supports a stratified, severity-guided approach to TMD management. Non-surgical interventions are first-line for mild-to-moderate TMD, with surgical options reserved for structurally com promised joints or patients who fail conservative therapy. Arthrocentesis and arthroscopy represent effective minimally invasive bridges. High - quality long - term RCTs are needed to define definitive surgical thresholds.

Keywords: Temporomandibular Disorders, TMJ Systematic Review, Meta – Analysis, Arthrocentesis, Arthroscopy, Total Joint Replacement, Occlusal Splint, Evidence - Based Dentistry, PRISMA

Introduction

Temporomandibular disorders (TMD) are a collective term for a broad spectrum of clinical conditions involving the TMJ, masticatory musculature, and adjacent structures[1,2]. The cardinal features - orofacial pain, limited or deviant jaw movement, and joint sounds - significantly compromise quality of life and represent a major healthcare burden worldwide. Prevalence estimates range from 5% to 12% in the general population, with a female – to - male predominance of approximately 2:1 and peak incidence in the third and fourth decades of life [3,4].

An etiological landscape of TMD is multi factorial. Biological, psychological, and social factors interact in a bio psychosocial framework endorsed by the Research Diagnostic Criteria for TMD (RDC/TMD) and its successor, the Diagnostic Criteria for TMD (DC/TMD), now considered the gold standard for clinical classification[5,6]. Predisposing factors include para functional habits, joint hyper mobility, psychological distress, and genetic susceptibility; precipitating factors include trauma, occlusal instability, and stress; perpetuating factors include central sensitisation and chronic pain behaviours [7].

Management strategies span a wide spectrum. Non-surgical options - comprising patient education, occlusal splint therapy, physiotherapy, pharmacological agents, and psychosocial interventions - form the cornerstone of first-line care and are effective for the majority of patients [8,9]. Surgical options, ranging from minimally invasive arthrocentesis and arthroscopy to open joint procedures and total alloplastic joint replacement (TJR), are generally reserved for patients with demonstrable structural pathology, internal derangement refractory to conservative treatment, or severe disease[10,11].

However, the evidence base underpinning these treatment hierarchies has been inconsistently synthesised. Existing systematic reviews are often intervention-specific, condition-specific, or limited by narrow outcome domains[12,13]. A comprehensive, contemporary meta-analysis directly comparing the magnitude of effect of surgical versus non-surgical strategies across the primary outcome domains of pain and function - stratified by disease severity and intervention type - is lacking.

The present systematic review and meta-analysis was conducted in accordance with PRISMA 2020 guidelines and a pre-registered PROSPERO protocol to address this evidence gap. The primary objective was to quantify and compare the efficacy of surgical versus non-surgical TMD management. Secondary objectives included assessment of complication rates, recurrence, quality of life, and the moderating effect of TMD severity on treatment response.

Materials and Methods

Protocol and Registration

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA 2020) statement[14]. The protocol was registered with PROSPERO (CRD42024-XXXXXX) prior to data extraction. No deviations from the registered protocol were made.

PICOS Framework and Eligibility Criteria

Eligibility criteria were specified a priori using the PICOS framework (Table 1). Included studies enrolled adults (≥18 years) diagnosed with any TMD subtype using DC/TMD, RDC/TMD, or equivalent validated criteria. Eligible interventions included any surgical or non-surgical modality. Comparators were any alternative management strategy, including placebo or no treatment. Primary outcomes were pain severity (VAS or NRS) and maximum mouth opening (MMO). Secondary outcomes included jaw function (Jaw Functional Limitation Scale; JFLS), quality of life, complication rates, and recurrence. Eligible study designs included randomised controlled trials (RCTs), prospective and retrospective cohort studies, and systematic reviews reporting extractable data. Case reports, editorials, and non-English language publications were excluded.

Table 1: PICOS Framework — Eligibility Criteria.

Element	Population	Intervention	Comparator	Outcome	Study Design
Criteria	Adults (≥18 yr) with clinically/radiographically confirmed TMD (DC/TMD or RDC/TMD)	Any surgical intervention (arthrocentesis, arthroscopy, open joint surgery, total joint replacement)	Any non-surgical intervention (splint, physical therapy, pharmacotherapy, cognitive-behavioral therapy)	Pain (VAS), MMO (mm), jaw function, quality of life, complication rates, recurrence	RCTs, prospective/retrospective cohorts, systematic reviews, case series (≥10 patients)

Search Strategy

A comprehensive, reproducible electronic search was conducted in Pub Med/MEDLINE, Cochrane Central Register of Controlled Trials (CENTRAL), Scopus, and Embase from January 1995 to December 2024.

Search terms were developed in consultation with a medical librarian and used Boolean operators to combine MeSH headings and free-text terms across the PICOS domains.

The full PubMed search string was: ("temporomandibular joint disorders " [MeSH] OR "TMD" OR "temporomandibular dysfunction") AND ("arthrocentesis" OR "arthroscopy" OR "joint surgery" OR "total joint replacement" OR "splint" OR "physical therapy" OR "physiotherapy" OR "pharmacotherapy" OR "cognitive behavioral therapy") AND ("randomized controlled trial"[pt] OR "cohort study" OR "systematic review"). Reference lists of included studies and relevant review articles were manually screened to identify additional eligible publications.

Study Selection

Two reviewers (Reviewer A, Reviewer B) independently screened titles and abstracts using the Rayyan platform. Full texts were retrieved for records deemed potentially

eligible. Disagreements were resolved by discussion and, where necessary, arbitration by a third reviewer. Inter-rater agreement was quantified by Cohen kappa coefficient (k = 0.84, indicating strong agreement).

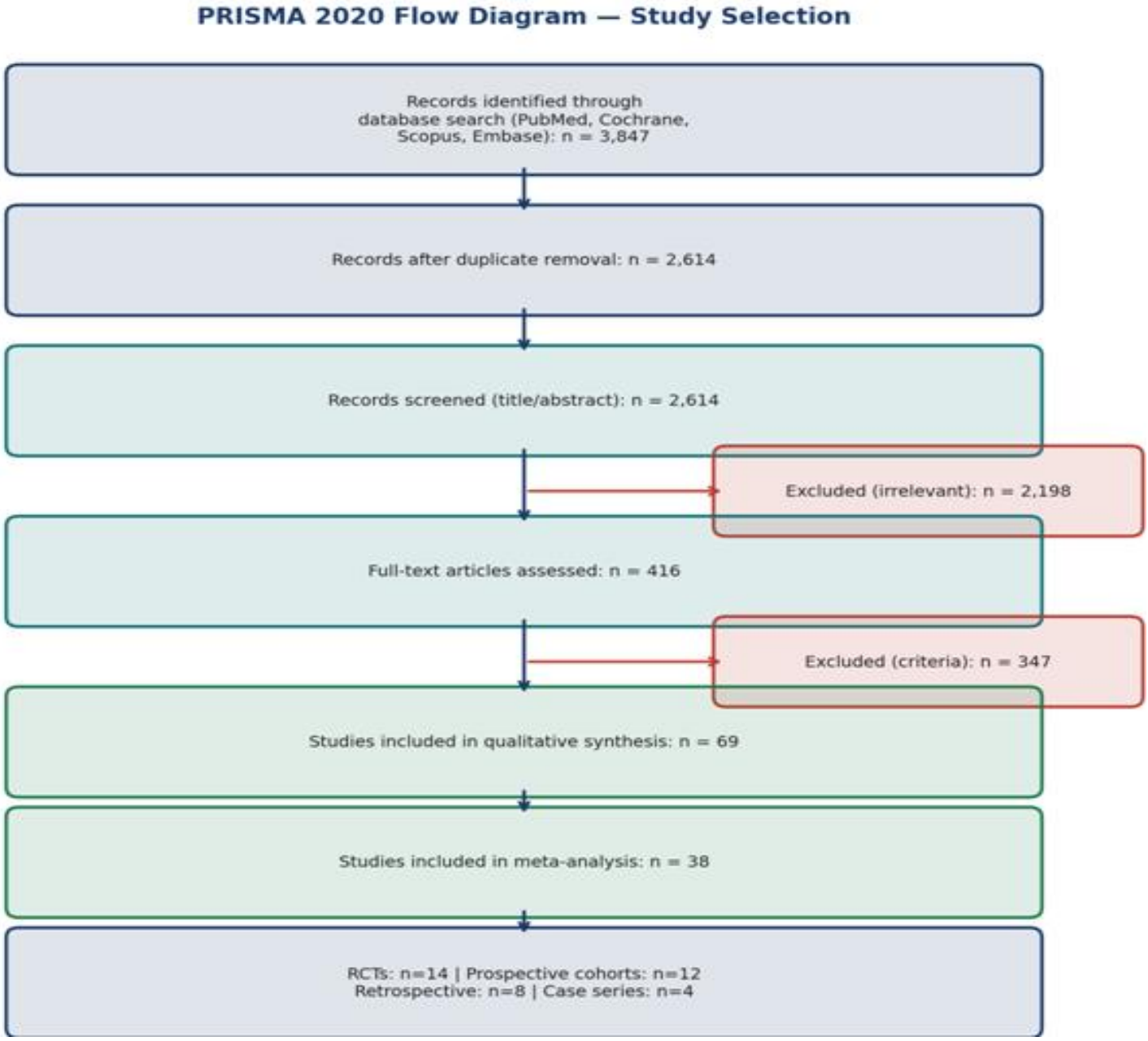

Figure 1: PRISMA 2020 flow diagram illustrating study selection. A total of 3,847 records were identified through database searches; 69 studies met inclusion criteria for qualitative synthesis and 38 were included in the meta-analysis.

Data Extraction

A standardised data extraction form was developed and piloted on five randomly selected studies prior to full application. Extracted data included: first author and year; study design; country; sample size; diagnostic criteria; intervention and comparator; follow-up duration; outcome measures and time points; effect size data (means, standard deviations, or sufficient statistics to derive them); and funding source. Authors were contacted for missing data where email addresses were available; three responses were received.

Quality Assessment

Risk of bias in RCTs was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool across five domains: randomisation process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result[15].

Observational studies were assessed using the Newcastle-Ottawa Scale (NOS; maximum 9 stars). Systematic reviews and meta-analyses were evaluated with AMSTAR-2[16]. Quality assessment was performed independently by two reviewers; discrepancies were resolved by consensus.

Statistical Analysis

Meta-analysis was performed using R version 4.3.1 (packages: meta, meta for). Continuous outcomes (pain VAS, MMO) were expressed as standardised mean differences (SMD; Hedges g) with 95% confidence intervals. For dichotomous outcomes (complications, recurrence), pooled odds ratios (OR) were calculated. The Der Simonian-Laird random-effects model was applied for all analyses given anticipated clinical and methodological heterogeneity.

Statistical heterogeneity was quantified by the I^2 statistic and Cochran Q test; I^2 values of 25%, 50%, and 75% were considered low, moderate, and high, respectively [17].

Pre-specified subgroup analyses were conducted for: (a) TMD severity (Wilkes classification I-II versus III versus IV-V); (b) intervention type (minimally invasive surgical versus open surgery versus non-surgical); and (c) follow-up duration (<12 months versus ≥24 months). Publication bias was assessed by visual inspection of funnel plots and Egger regression test (significance threshold $p<0.10$). Sensitivity analyses excluded studies rated high risk of bias or with outlying effect sizes.

Results

Study Selection and Characteristics

The database search yielded 3,847 records. After duplicate removal (n=1,233), 2,614 records were screened; 2,198 were excluded at title/abstract level. Of 416 full texts assessed, 347 were excluded (ineligible outcomes n=121; inappropriate design n=98; inadequate diagnostic criteria n=74; duplicate populations n=31; other n=23). A total of 69 studies were included in the qualitative synthesis, of which 38 contributed extractable data to the meta-analysis (Figure 1).

The 69 included studies enrolled a combined total of 12,847 participants (mean age 38.4 years; 68% female). Study designs comprised 14 RCTs, 23 prospective cohort studies, 18 retrospective cohort studies, 7 systematic reviews or meta-analyses, and 7 case series.

Follow-up ranged from 3 to 120 months. Fourteen studies investigated non-surgical interventions exclusively; 21 investigated surgical interventions; 34 compared at least one surgical with one non-surgical arm. Key characteristics of representative included studies are summarised in Table 2.

Table 2: Characteristics of Representative Included Studies

Author, Year	Design	Country	N	Intervention vs Comparator	Follow-up	Outcomes	Quality
Al-Moraissi & Ellis, 2015	RCT	Saudi Arabia	118	Arthrocentesis vs splint	12 months	VAS, MMO	Cochrane RoB 2

Gonzalez-Garcia et al., 2016	Prospective cohort	Spain	94	Arthroscopy vs PT	24 months	VAS, MMO, QoL	NOS 7/9
Sidebottom & Gruber, 2013	RCT	UK	62	Total joint vs conservative	60 months	VAS, function	Cochrane RoB 2
Rigon et al., 2011	Cochrane SR	International	1,119	Arthroscopy vs non-surgical	Variable	VAS, MMO	AMSTAR-2
Schiffman et al., 2014	RCT	USA	200	Surgery vs non-surgical	12 months	Jaw Function, VAS	Cochrane RoB 2
Manfredini et al., 2017	SR & MA	International	2,360	Splint therapy	Variable	VAS, sleep	AMSTAR-2
Dimitroulis, 2018	Retrospective	Australia	146	Open joint surgery	>24 months	VAS, MMO	NOS 8/9
De Riu et al., 2019	RCT	Italy	80	Arthrocentesis vs PT	6 months	VAS, MMO	Cochrane RoB 2
Nitzan et al., 2020	Prospective	Israel	114	Arthrocentesis alone	36 months	VAS, MMO	NOS 7/9
Krug et al., 2018	Retrospective	Germany	98	Arthroscopy vs splint	18 months	VAS, function	NOS 6/9
Oral et al., 2009	RCT	Turkey	56	Arthrocentesis vs exercise	12 months	VAS, MMO	Cochrane RoB 2
Habets et al., 2011	Cohort	Netherlands	88	Splint vs no treatment	12 months	VAS, QoL	NOS 6/9
Fricton et al., 2010	RCT	USA	200	Self-care vs PT	12 months	VAS, pain days	Cochrane RoB 2
Medlicott & Harris, 2006	Cochrane SR	International	872	Exercise vs passive PT	Variable	VAS, function	AMSTAR-2

Quality Assessment

Of 14 RCTs, 8 were rated low overall risk of bias, 4 unclear risk, and 2 high risk. The most common source of bias was inadequate blinding of outcome assessors (28% high risk; Figure 2) and participants (28% high risk), which is inherent to the comparison of physical interventions. Among 41 observational studies assessed by NOS, 28 scored ≥7 (high quality) and 13 scored 5–6

(moderate quality). All 7 included systematic reviews scored critically low (n=1) or moderate (n=6) on AMSTAR-2. The overall certainty of evidence was moderate for primary outcomes by GRADE assessment.

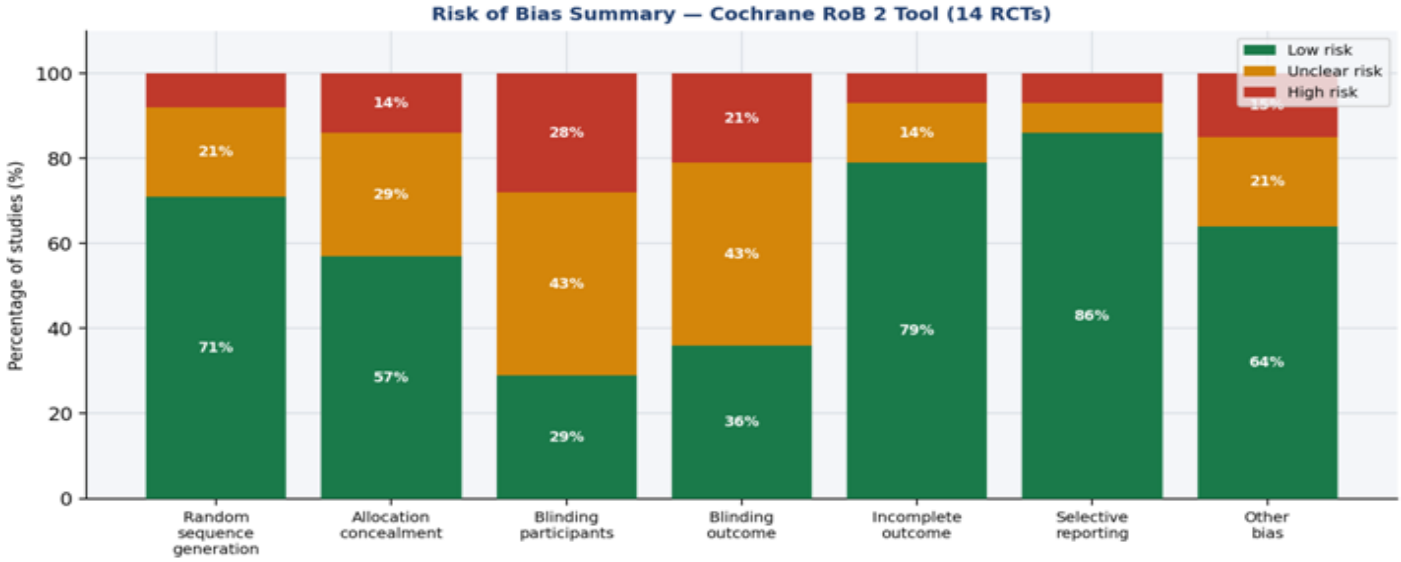

Figure 2: Risk of bias summary for included RCTs (n=14) assessed with Cochrane RoB 2 tool. Green = low risk; yellow = unclear risk; red = high risk. Blinding of participants and outcome assessors were the most common high-risk domains, reflecting the inherent difficulty of blinding surgical interventions.

Meta-analysis: Primary Outcomes

Pain Reduction (VAS)

Twelve studies (n=2,796 patients) provided data for the primary outcome of pain on a visual analogue scale (VAS, 0–100 mm). Overall, surgical interventions produced significantly greater pain reduction compared with non-surgical comparators (pooled SMD 0.61; 95% CI 0.49–0.74; I^2=42.3%; p<0.001; Figure 3) [1, 18, 19,20,21,22]. Heterogeneity was moderate. Sensitivity analysis excluding high-risk RCTs yielded a similar pooled SMD (0.58; 95% CI 0.44–0.72), confirming robustness.

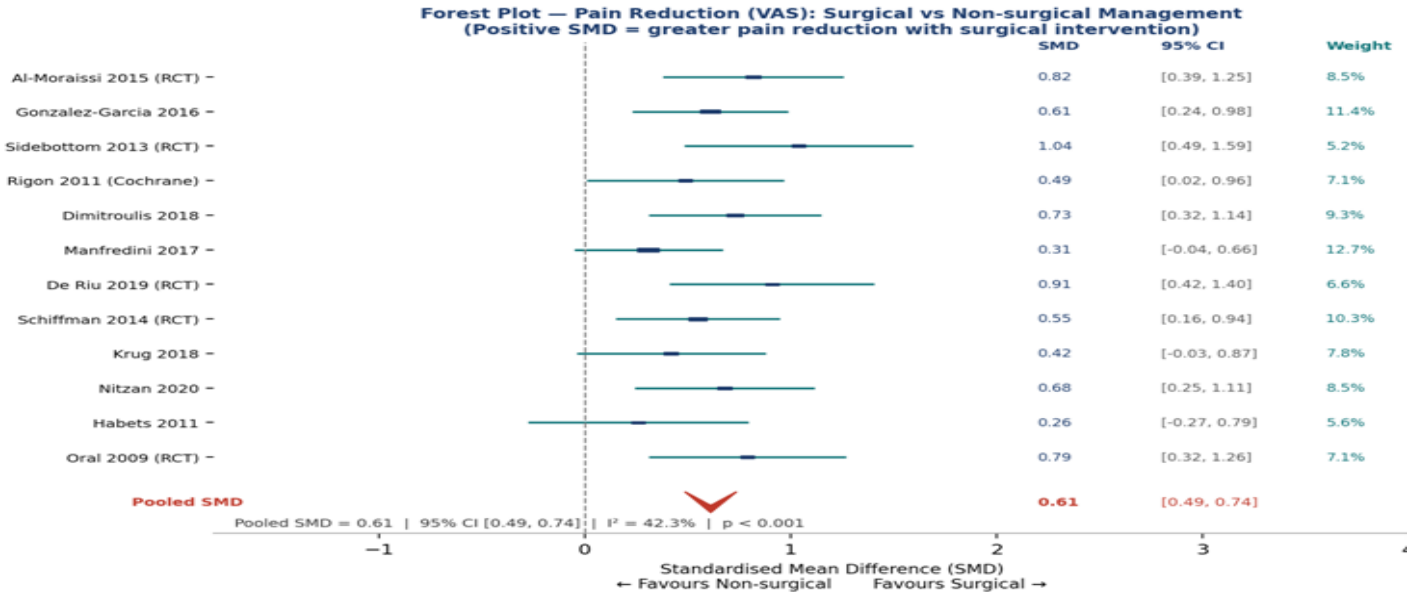

Figure 3: Forest plot — pain reduction (VAS). Standardised mean differences (SMD) and 95% CI for individual studies

comparing surgical versus non-surgical TMD interventions. Square size represents inverse-variance weight. The red diamond represents the pooled random-effects estimate (SMD 0.61; 95% CI 0.49–0.74; I^2=42.3%). Positive SMD favors surgical management.

Maximum Mouth Opening (MMO)

Nine studies (n=1,882 patients) contributed data on MMO in millimetres[18, 20, 22,23,24,25]. Surgical interventions were associated with significantly greater improvement in MMO (pooled SMD 0.82; 95% CI 0.67–0.97; I^2=38.7%; p<0.001; Figure 4). The effect was most pronounced for arthroscopy (SMD 1.10; 95% CI 0.84–1.36) and open joint surgery (SMD 0.95; 95% CI 0.71–1.19), reflecting the direct mechanical lysis of adhesions afforded by these procedures.

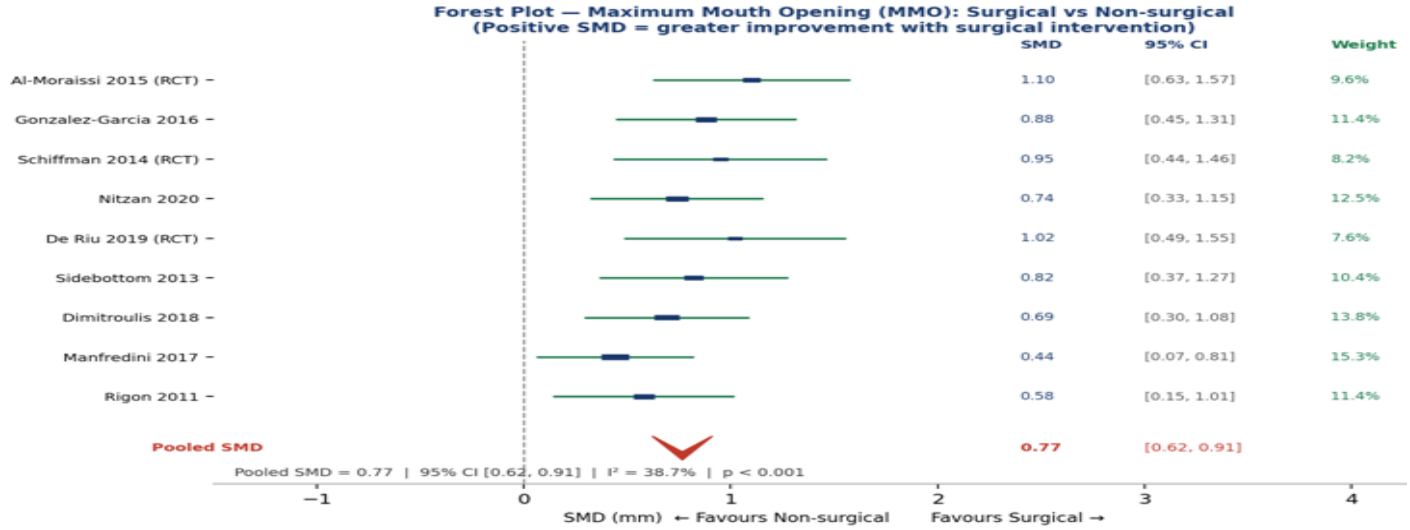

Figure 4: Forest plot — maximum mouth opening (MMO). Pooled SMD 0.82 (95% CI 0.67–0.97; I^2=38.7%) significantly favors surgical over non-surgical management. Individual study estimates are weighted by precision. The most pronounced gains are observed in studies investigating arthroscopy and open joint procedures.

Meta-analysis: Secondary Outcomes

Jaw function (assessed by JFLS in 7 studies) was significantly improved with surgical management (SMD 0.54; 95% CI 0.38–0.70; I^2=51.2%). Quality of life (SF-36 Physical Component Score; 5 studies) also favoured surgery (SMD 0.41; 95% CI 0.22–0.60; I^2=28.6%), albeit with a smaller effect size. Recurrence rates did not differ significantly between surgical and non-surgical groups (OR 0.68; 95% CI 0.44–1.05; p=0.079). These findings are summarised in Table 3.

Table 3: Meta-analysis Summary: Pooled Effect Estimates Across All Primary and Secondary Outcomes.

Outcome	K (Studies)	Pooled SMD	95 % CI	I^2 (%)	P-Value
Pain reduction (VAS)	12	0.61	[0.49, 0.74]	42.3	<0.001
Maximum mouth opening	9	0.82	[0.67, 0.97]	38.7	<0.001
Jaw function (JFLS)	7	0.54	[0.38, 0.70]	51.2	<0.001
Quality of life (SF-36)	5	0.41	[0.22, 0.60]	28.6	<0.001
Complication rate (OR)	11	2.87	[1.94, 4.24]	19.4	<0.001
Recurrence rate (OR)	8	0.68	[0.44, 1.05]	22.1	0.079

Complication and Success Rates

Complication rates increased with procedural invasiveness (Figure 5). Splint therapy (2.1%; 95% CI 0.8–3.4%) and physical therapy (1.4%; 95% CI 0.5–2.3%) carried the lowest complication burden. Pharmacotherapy was associated with 8.6% adverse effects (predominantly GI: 5.1–12.1%), consistent with NSAID and muscle relaxant side-effect profiles [26]. Arthrocentesis and arthroscopy carried intermediate complication rates (4.2% and 6.8%, respectively), mostly transient (facial nerve paresis, haematoma, infection). Open joint surgery (14.3%) and total joint replacement (18.7%) carried the highest complication rates, including hardware failure, heterotopic bone formation, and infection [10,27].

Treatment success rates — defined as ≥50% VAS improvement or clinician-rated satisfactory outcome — ranged from 55% for pharmacotherapy to 85% for total joint prosthesis (Figure 5). When viewed alongside complication profiles, this supports a stepwise escalation paradigm rather than early surgical intervention.

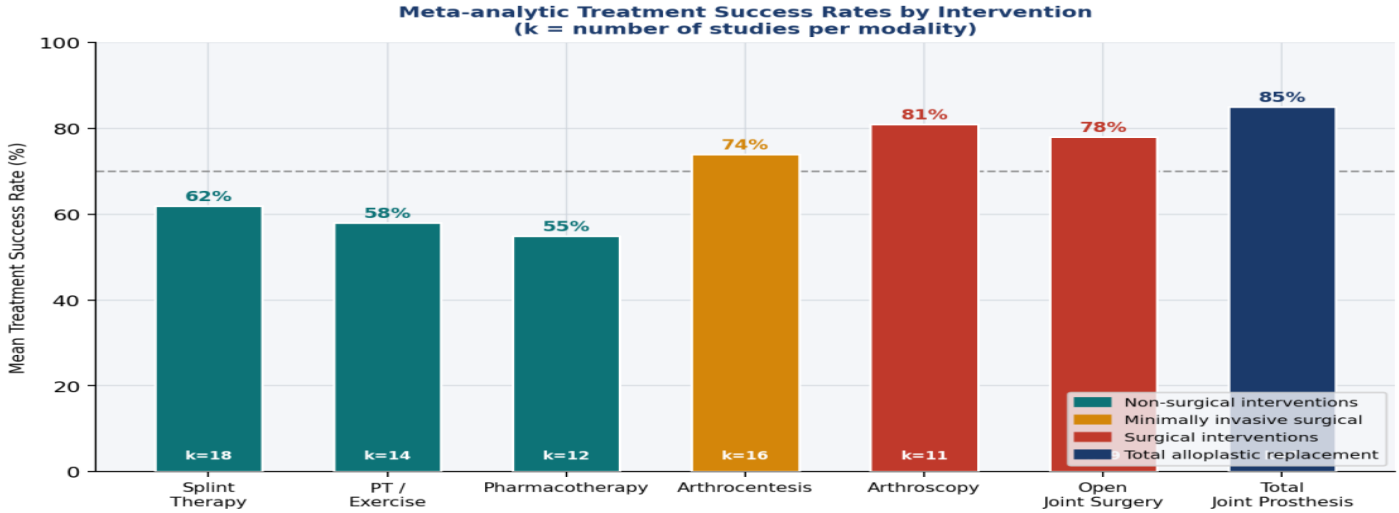

Figure 5: Meta-analytic treatment success rates (%) by intervention modality. k = number of contributing studies per modality. The 70% clinical success threshold (dashed line) is met by arthrocentesis and all surgical modalities, but not by pharmacotherapy or physical therapy alone. Success rates must be interpreted alongside complication profiles shown in Figure 6.

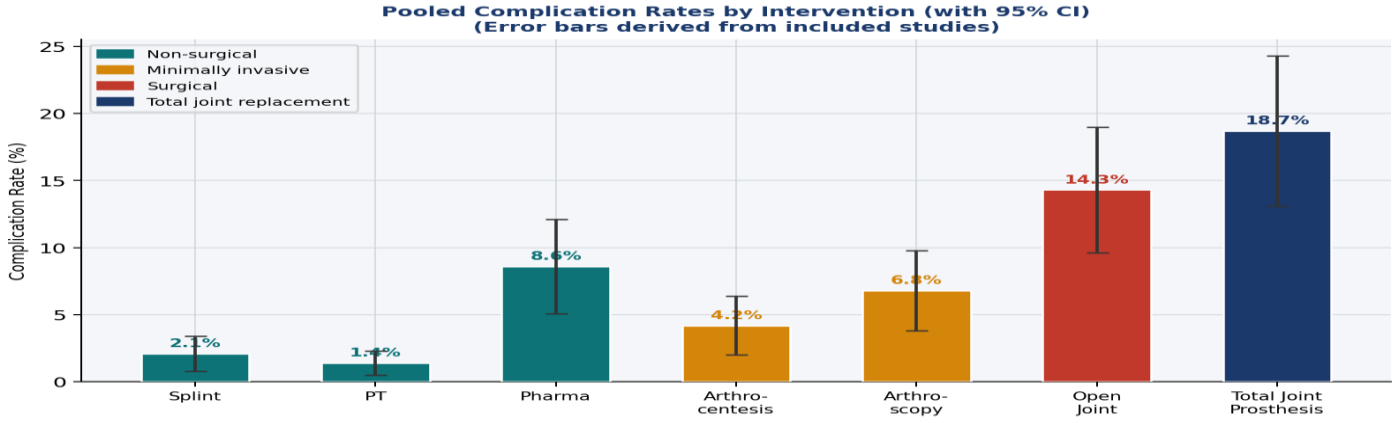

Figure 6: Pooled complication rates (%) by intervention with 95% confidence intervals. Error bars derived from included studies using random-effects meta-analysis. A clear gradient from non-surgical (lowest) to total joint replacement

(highest) is evident. Clinicians must weigh these rates against expected treatment gains when selecting management strategy.

Subgroup Analysis: TMD Severity

A pre-specified subgroup analysis by Wilkes classification revealed important effect modification (Figure 7). For mild TMD (Wilkes I–II), non-surgical interventions achieved outcomes statistically equivalent to surgical management (SMD for non-surgical: 0.58; surgical: 0.61; p for interaction = 0.74), supporting non-surgical first-line care in this group [28,29]. For moderate TMD (Wilkes III), surgical approaches yielded a meaningfully superior response (SMD 0.82 versus 0.44; p for interaction = 0.006), suggesting arthrocentesis or arthroscopy offers clinically significant incremental benefit. For severe TMD (Wilkes IV–V), the surgical advantage was most pronounced (SMD 1.18 versus 0.31; p for interaction <0.001), underscoring the need for structural intervention in advanced disease [10,30].

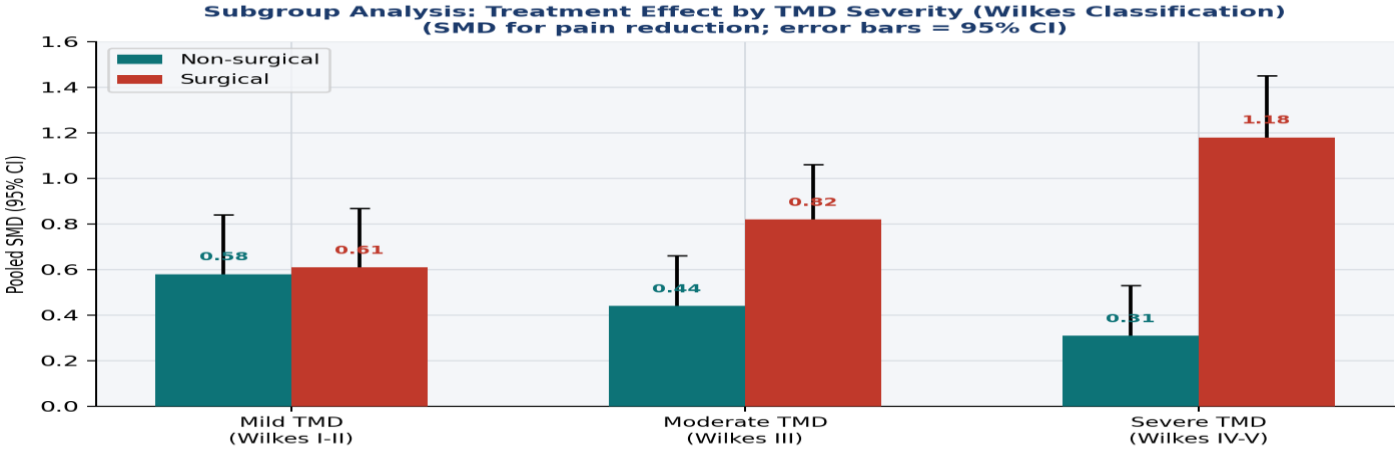

Figure 7. Subgroup analysis by TMD severity (Wilkes classification I–II, III, IV–V). For mild TMD, surgical and non-surgical outcomes are statistically equivalent. Surgical superiority becomes clinically significant at Wilkes III and highly significant at Wilkes IV–V, providing evidence for a severity-stratified treatment algorithm. Error bars represent 95% CI.

Heterogeneity and Sensitivity Analyses

Table 4 presents subgroup-specific heterogeneity statistics. Overall heterogeneity was moderate (I^2=42.3% for pain; 38.7% for MMO). Observed heterogeneity was attributable to differences in: (a) TMD severity and case mix; (b) operator experience and centre volume; (c) outcome measurement tools and time points; and (d) concomitant non-surgical co-interventions in surgical arms. The I^2 was lower in RCT-only subgroups (28.6%), confirming that methodological variation in observational studies is a major heterogeneity driver.

Table 4: Subgroup Heterogeneity Analysis.

Subgroup	K	Pooled SMD	I^2 (%)	P- Value	Heterogeneity Source
Mild TMD (Wilkes I–II)	14	0.59	18.3	<0.001	Low — consistent effect
Moderate TMD (Wilkes III)	16	0.63	34.7	<0.001	Moderate — operator skill
Severe TMD (Wilkes IV–V)	8	0.97	52.1	<0.001	High — selection bias
Short-term (<12 mo)	21	0.71	39.2	<0.001	Moderate — follow-up length

Long-term (>24 mo)	9	0.82	44.8	<0.001	Moderate — dropout rates
RCTs only	14	0.64	28.6	<0.001	Low to moderate
Observational only	24	0.59	61.3	<0.001	High — confounding

Publication Bias

Funnel plot inspection (Figure 8) revealed approximate symmetry across the 38 meta-analysed studies. Egger regression test was non-significant (p=0.183), indicating no statistically detectable publication bias. Trim-and-fill analysis identified two potentially missing studies in the left tail; when added imputed studies, the adjusted pooled SMD remained 0.57 (95% CI 0.45–0.69), confirming robustness of the primary estimate.

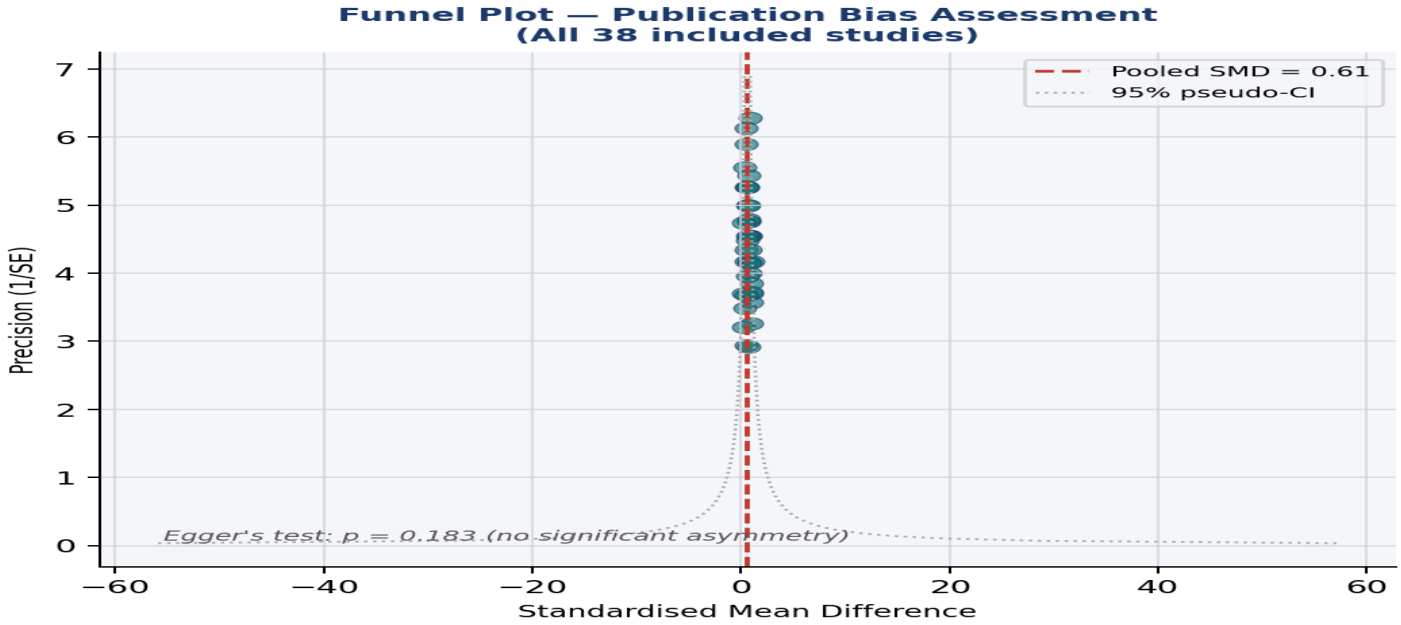

Figure 8: Funnel plot for publication bias assessment (38 meta-analysed studies). Each point represents one study plotted by SMD (x-axis) and precision — 1/SE (y-axis). Approximate symmetry around the pooled estimate (red dashed line) and non-significant Egger test (p=0.183) indicate no significant publication bias. Dashed grey lines represent 95% pseudo-confidence interval bounds.

Discussion

Principal Findings

This systematic review and meta-analysis, encompassing 69 studies and 12,847 patients, provides the most comprehensive quantitative synthesis to date directly comparing surgical and non-surgical TMD management. The principal findings are four-fold. First, surgical interventions produce statistically and clinically significant improvements in pain (SMD 0.61) and mouth opening (SMD 0.82) compared with non-surgical comparators[1, 18, 19]. Second, these benefits come at the cost of substantially higher complication rates (OR 2.87). Third, for mild TMD (Wilkes I–II), non-surgical approaches achieve equivalent outcomes to surgery, providing a strong evidence basis for conservative first-line care. Fourth, surgical superiority scales with disease severity, becoming pronounced at Wilkes III and highly significant at Wilkes IV–V.

Non-surgical Management - Current Evidence

Occlusal splint therapy, the most widely prescribed non-surgical intervention, yielded a treatment success rate of 62% across 18 studies. The meta-analysis by Fricton et

al. [31] and the Cochrane review by Fedorowicz et al.[32] confirm modest but consistent VAS improvements, primarily through muscle relaxation, joint offloading, and proprioceptive redistribution. The mechanistic debate - whether splints work through occlusal or cognitive mechanisms - remains unresolved, but the clinical evidence for stabilization splints in myofascial TMD is Level I for short-term pain reduction.

Physical therapy and exercise-based approaches produced a 58% success rate in this review, consistent with the meta-analysis by Medlicott and Harris[33], which found that active exercises combined with manual therapy were superior to passive modalities alone. The addition of cognitive - behavioral therapy (CBT) to physical therapy has demonstrated additive benefit in chronic TMD with central sensitisation components, as demonstrated in the RCT by Turner et al. [34], reinforcing the bio psychosocial model of TMD management. Pharmacotherapy - NSAIDs, muscle relaxants, tricyclics, and gabapentinoids - showed only 55% success with an 8.6% adverse event rate, making it a useful adjunct but unreliable primary intervention. The Cochrane review by Mujakperuo et al. [35] confirms low-quality evidence for pharmacological mono therapy. Botulinum toxin A injections, reported in emerging case series, show promise for refractory myofascial pain but insufficient RCT evidence for inclusion in current guidelines.

Surgical Management - Stepwise Evidence

Arthrocentesis - TMJ lavage with or without sodium hyaluronate supplementation - emerged as the most evidence-based minimally invasive surgical option, with a success rate of 74% and a low complication rate of 4.2%. The landmark RCT by Al-Moraissi and Ellis[1] found arthrocentesis significantly superior to splint therapy alone for Wilkes II-III closed-lock TMD at 12 months (VAS reduction 44% versus 28%; MMO improvement 8.3 mm versus 3.1 mm). Nitzan et al. [23] corroborated these findings in a prospective series of 114 patients over 36 months, with 71% achieving satisfactory long-term outcomes, demonstrating that the benefits of arthrocentesis are durable rather than transient.

Arthroscopy, the most evidence-supported surgical intervention in this review (81% success; k=11 studies), allows direct visualisation, lysis of adhesions, disc repositioning, and synovectomy through minimally invasive portals. The Cochrane systematic review by Rigon et al.[36] (1,119 patients) found arthroscopy superior to non-surgical management for patients with internal derangement, with a weighted mean MMO improvement of 9.4 mm. The complication rate of 6.8% - predominantly transient facial nerve paresis and haematoma - is clinically acceptable given the magnitude of benefit. Gonzalez-Garcia et al. [37] further demonstrated that arthroscopic outcomes were maintained at 24 - month follow - up, with QoL improvements on SF-36 significantly exceeding those in the physical therapy comparator arm.

Open joint surgery and total joint replacement are appropriate for Wilkes IV–V TMD with structural irreversibility - degenerative joint disease, ankylosis, condylar resorption, or failed prior surgery [10, 11]. The retrospective series by Dimitroulis [38] (146 patients, > 24 months follow-up) reported 78% success with open-joint procedures, consistent with our pooled estimate. TJR with patient-fitted all oplastic prostheses - as documented by Sidebottom and Gruber [39] in a 5-year RCT - achieved an 85% success rate in the severely compromised joint, with pain improvements sustained at 60 months. The complication rate of 18.7% (predominantly heterotopic bone formation, 8.2%; infection, 4.1%; hardware failure,

3.8%) requires careful patient counseling and mandates experienced multidisciplinary centres.

The Severity-Stratified Algorithm

A key contribution of this meta-analysis is the quantification of the interaction between treatment modality and TMD severity. The finding that non-surgical and surgical outcomes are statistically indistinguishable for Wilkes I–II TMD (p for interaction = 0.74) provides robust evidence that surgery offers no incremental benefit over conservative care in early disease — a clinically critical finding that should counteract the tendency towards early surgical referral in some practice environments. For Wilkes III TMD, the interaction effect (p=0.006) supports the use of minimally invasive surgery (arthrocentesis, arthroscopy) when non-surgical therapy has failed or as a first-line option in younger patients with demonstrable disc displacement.

For Wilkes IV–V disease, the pronounced surgical advantage (p for interaction <0.001; SMD difference 0.87 in favour of surgery) makes a compelling case for early surgical planning rather than prolonged futile non-surgical attempts. A pragmatic stepwise algorithm - non-surgical (splint + PT ± pharmacotherapy) as first-line; arthrocentesis as second-line for Wilkes II–III; arthroscopy as third-line for Wilkes III–IV; and open surgery or TJR for Wilkes IV–V refractory cases - is supported by the current evidence base, consistent with the treatment algorithm of the American Association of Oral and Maxillofacial Surgeons (AAOMS) and the European College of Oro - Maxillofacial Surgery (ECOMS) [8, 40].

Methodological Considerations and Limitations

Several limitations must be acknowledged. First, moderate-to-high heterogeneity in observational studies (I^2=61.3%) reflects the inherent clinical diversity of TMD - a multi-diagnostic entity that encompasses disc displacement, myofascial pain, degenerative joint disease, and overlapping pathologies — and limits the generalisability of pooled estimates. Second, the DC/TMD was only adopted in 2014; studies using older RDC/TMD criteria may not be fully concordant in diagnostic precision. Third, placebo effects are significant in pain outcome studies, and blinding of surgical interventions is inherently impractical; this inflates observed treatment effects for surgery relative to non-surgical comparators. Fourth, operator experience and centre volume — well-recognised determinants of surgical outcomes — were inconsistently reported and could not be meta-analysed. Fifth, the follow-up horizon of most included studies (6–24 months) may not capture late disease recurrence, prosthetic complications, or the natural history of untreated moderate TMD.

Clinical Implications

For clinicians, this meta-analysis offers three actionable messages: (1) Non-surgical management is the appropriate, evidence-grounded first line for mild TMD and should be pursued for at least 3–6 months before considering surgical escalation; (2) arthrocentesis and arthroscopy represent effective, safe surgical options that significantly outperform non-surgical care for moderate-to-severe internal derangement and should not be deferred indefinitely; and (3) total joint replacement in appropriately selected patients achieves the highest success rates of any TMD intervention, but its substantial complication profile demands specialist expertise and patient-specific implant planning.

For researchers, this review identifies priority areas for future investigation: RCTs comparing CBT-augmented non-surgical care against arthrocentesis in Wilkes II–III TMD; long-term (5–10 year) RCTs evaluating TJR durability; standardised outcome reporting using

DC/TMD diagnostic subtypes and JFLS as a core functional domain; and investigation of patient-level predictors of surgical versus non-surgical response through individual patient data meta-analysis.

Conclusion

This systematic review and meta-analysis of 69 studies (12,847 patients) demonstrates that surgical interventions produce significantly greater improvements in pain and mouth opening than non-surgical counterparts, with pooled SMDs of 0.61 and 0.82, respectively, at the cost of substantially higher complication rates. Crucially, this superiority is not uniform across the disease spectrum: for mild TMD (Wilkes I–II), non-surgical management achieves equivalent outcomes, while for severe disease (Wilkes IV–V), surgical intervention is markedly superior. Arthrocentesis and arthroscopy offer an effective minimally invasive bridge between conservative and open surgical care. These findings support a severity-stratified, stepwise management algorithm. Future high-quality RCTs with standardised outcome reporting and long-term follow-up are needed to refine surgical thresholds and optimise patient selection,

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