Systematic Review

Cephalometric Assessment and Long-Term Stability of Anterior Open-Bite Correction with Skeletal Anchorage: A Systematic Review and Meta-Analysis

Alessandro Ugolini [1], Margherita Donelli [2,3], Alessandro Bruni [4], Nunzio Cirulli [5], Massimo Berlen [4], Andrea Abate [1,*] and Valentina Lanteri [4]

[1] Department of Sciences Integrated Surgical and Diagnostic, University of Genova, 16132 Genova, Italy; alessandro.ugolini@unige.it
[2] Department of Biomedical Surgical and Dental Sciences, University of Milan, 20142 Milan, Italy; margherita.donelli@unimi.it
[3] Fondazione IRCCS Cà Granda, Ospedale Maggiore Policlinico, 20142 Milan, Italy
[4] Surgical, Medical and Dental Department, University of Modena and Reggio Emilia, 41124 Modena, Italy; alebruni@unimore.it (A.B.); 213628@studenti.unimore.it (M.B.); valentina.lanteri@unimi.it (V.L.)
[5] Department of Interdisciplinary Medicine, University of Bari "Aldo Moro", 70124 Bari, Italy; dottore@studiocirulli.it
* Correspondence: andreabate93@gmail.com; Tel.: +39-33-177-12541

Featured Application

This review supports the clinical use of temporary anchorage devices (TADs) as a minimally invasive alternative to orthognathic surgery for the correction of anterior open bite (AOB) in selected patients. The findings can guide treatment planning by highlighting the skeletal and dentoalveolar changes achievable with TADs and their reported long-term stability.

Abstract

This systematic review evaluated the dento-skeletal effects and long-term stability of anterior open-bite (AOB) correction with temporary anchorage devices (TADs). A comprehensive search up to May 2025 was conducted in PubMed, Scopus, Web of Science, Embase, Cochrane Library, LILACS, Scielo, Epistemonikos, Google Scholar, and ScienceDirect. Eligible studies included randomized and non-randomized trials and case series with cephalometric outcomes. Risk of bias was assessed with the MINORS tool. A qualitative synthesis was performed, and studies meeting criteria were included in the meta-analysis. Ot of 1885 records, 22 studies were included qualitatively; 5 entered meta-analysis. Treatment yielded a mean overbite increase of 5.6 mm and reduction in N-Me of 2.8 mm. FMA and SN-GoMe decreased by about 2° and 1.6°, ANB by 1.7°, while SN-Pog increased by 1.4°. Most studies reported stability up to 3 years. Despite heterogeneity and predominance of non-randomized studies, evidence suggests TADs effectively correct AOB through overbite improvement and mandibular counterclockwise rotation. Reported effects appear stable, supporting skeletal anchorage as a reliable, less invasive alternative to surgery in selected patients.

Keywords: anterior open bite; cephalometry; skeletal anchorage; malocclusion

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1. Introduction

Anterior open bite (AOB), defined as the absence of vertical overlap between the maxillary and mandibular incisors when the posterior teeth are in occlusion, represents

one of the most challenging malocclusions due to its multifactorial etiology and high relapse rate, particularly in non-growing patients [1]. Its prevalence is notably higher in individuals with hyperdivergent skeletal patterns and varies by ethnicity, ranging from 1.4% to 3.5% among Caucasians, and from 9.1% to 16.5% among African American populations [2]. Etiological factors contributing to AOB are both genetic and environmental. Environmental factors include deleterious oral habits such as pacifier and thumb-sucking, anterior tongue posture and tongue thrust, mouth breathing, and upper airway obstruction due to conditions like adenoidal hypertrophy, allergic rhinitis, deviated nasal septum, or enlarged tonsils. These may act in conjunction with a genetic predisposition and vertical skeletal growth disturbances, increasing the risk of developing AOB [2–4].

AOB can severely impact esthetics, masticatory function, speech, and psychosocial well-being, making its management both functionally and emotionally significant [1]. In adult patients, conventional treatment options include anterior tooth extrusion, vertical control of the posterior segment, and, in more severe cases, orthognathic surgery. However, such approaches often involve high biomechanical complexity, poor predictability, and variable long-term stability [5–7].

The advent of skeletal anchorage—particularly TADs such as miniscrews and miniplates—has provided a non-surgical alternative for AOB correction in non-growing patients [8–10]. These devices offer a high degree of anchorage control, enabling effective molar intrusion and facilitating counterclockwise mandibular autorotation, which in turn contributes to bite closure and facial profile enhancement [10–12]. Importantly, such mechanics do not rely on patient compliance and mimic, to some extent, the skeletal effects of maxillary impaction achieved through orthognathic surgery [13–15].

Despite promising short-term outcomes—including overbite improvement, skeletal mandibular advancement, and facial aesthetic enhancement—questions remain regarding the long-term stability of AOB correction with skeletal anchorage [6,16]. Relapse remains a major concern, influenced by factors such as tongue posture, neuromuscular adaptation, retention protocols, and the underlying vertical skeletal pattern [17]. Furthermore, the heterogeneity among studies—particularly in treatment protocols, TAD placement sites, applied force systems, and follow-up duration—limits the generalizability of findings and hinders the establishment of evidence-based clinical guidelines.

Although previous systematic reviews have explored the efficacy of skeletal anchorage for molar intrusion and openbite correction [6,7,10,11], Most of the studies primarily focused on short and medium-term dentoalveolar outcomes—such as overbite improvement—rather than comprehensive skeletal changes. Moreover, the long-term stability of these corrections has rarely been analyzed quantitatively, and relapse has often been assessed descriptively.

To date, the literature lacks a systematic and quantitative synthesis of longitudinal cephalometric changes, including long-term relapse assessment and potential contributing factors.

Therefore, the primary objective of this systematic review and meta-analysis is to evaluate the cephalometric changes associated with anterior open-bite correction using skeletal anchorage in non-growing patients, as well as to assess the long-term stability of these outcomes after at least one year of follow-up. Secondary objectives include quantifying relapse over different time intervals and comparing these findings with those reported for both surgical and non-surgical treatment approaches.

2. Materials and Methods

2.1. Protocol and Registration

This systematic review was reported in accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. This

comprehensive review protocol was registered in an online digital repository (OSF: https://osf.io/r6nf9, accessed on 10 August 2025) and modified in Augsut 2025.

2.2. Eligibility Criteria

The criteria used to determine study eligibility for inclusion in the present systematic review were defined according to the PICOS framework and are summarized in Table 1. The research question was developed in accordance with the FINER criteria to ensure methodological rigor and clinical relevance [18].

Table 1. Inclusion and exclusion criteria for study selection, structured according to the PICOS framework.

Category	Inclusion Criteria	Exclusion Criteria
Participants	− Studies including patients aged ≥12 years with permanent dentition (The age limit ≥18 years, was chosen for the quantitative analysis to minimize residual growth effects that could confound cephalometric changes). − Studies involving a homogeneous group of patients with anterior open bite	− In vitro studies − Animal studies − Studies involving patients with cleft lip/palate or other craniofacial anomalies − Studies including patients with systemic diseases or craniofacial syndromes
Intervention	− Anterior open bite treated with skeletal anchorage devices	− Studies not specifying the type of anchorage device − Studies with less than 6 months of post-retention follow-up
Comparison	− Studies assessing pre- and post-treatment outcomes	
Outcomes	− Cephalometric changes related to anterior open-bite correction	− Studies without cephalometric evaluation
Type of included Studies	− Randomized controlled trials (RCTs) − Non-randomized studies: prospective or retrospective (Given the limited number of randomized controlled trials in this field, both prospective and retrospective designs were included to capture the full scope of available clinical evidence).	− Case reports − Reviews and meta-analyses − Non-English articles − Letters to the editor or commentaries

The question guiding this systematic review was: In non-growing patients with anterior open bite (**P**), does treatment with skeletal anchorage devices (**I**), compared to baseline measurements (**C**), result in significant cephalometric changes and long-term stability of the correction (**O**), according to evidence from randomized and non-randomized clinical studies (**S**)?

2.3. Information Sources

A comprehensive electronic search was conducted up to May 2025 across the following databases: PubMed (Medline), Scopus, Web of Science, Embase, LILACS, Scielo, Cochrane Library, Epistemonikos, ScienceDirect, and Google Scholar. No restrictions were applied regarding publication year or geographic location.

Additionally, a manual search was performed by screening the reference lists of all eligible studies and relevant review articles to identify further potentially includable papers. Only articles published in English were considered for inclusion in this review.

2.4. Search Strategy

A structured search strategy was developed based on the predefined PICOS criteria and adapted to each database using appropriate controlled vocabulary (e.g., MeSH terms) and free-text keywords. The initial query string was constructed for PubMed (MEDLINE) and subsequently modified for use in the other databases.

Boolean operators (AND, OR) were applied to combine search terms and refine the results. The complete search strategies for all databases are reported in Table A1.

After retrieving all search results, references were imported into Rayyan (https://www.rayyan.ai, accessed on 15 May 2025), a web-based tool for systematic review management. Duplicate records were automatically removed using the platform's built-in function, followed by a manual screening to ensure the complete elimination of duplicates.

2.5. Selection Process

Following duplicate removal, the remaining records were screened for relevance based on their titles and abstracts. Two reviewers (A.A. and M.D.) independently conducted this process using the Rayyan web application (https://www.rayyan.ai, accessed on 15 May 2025), following the predefined PICOS criteria. In cases of uncertainty regarding a study's eligibility, the full text was retrieved and assessed independently by both reviewers. Any disagreements were resolved through discussion with a third author (A.B.).

2.6. Data Collection Process and Data Items

Data extraction was independently performed in duplicate by two reviewers (A.A. and M.D.), with disagreements resolved through discussion with a third author (A.B.). For each included study, the following information was extracted: authors and year of publication, study design, type of assessment, sample size, mean age, gender distribution, treatment duration, measurement methods, type of skeletal anchorage device used, force applied, site of application (maxillary/mandibular), follow-up duration, amount of open-bite reduction, effects on mandibular autorotation and facial morphology, outcomes assessed, reported side effects, and authors' conclusions.

The **primary outcomes** of interest were the following cephalometric variables:

- Overbite;
- ANB;
- N-Me;
- SN-GoMe;
- SN-Pog;
- FMA.

Secondary outcomes included mandibular autorotation, improvement in facial morphology, and relapse rate. Extracted data were synthesized and summarized in tabular format for qualitative and quantitative analysis.

2.7. Study Risk of Bias Assessment

Following data extraction, a qualitative assessment of the included studies was conducted using the Methodological Index for Non-Randomized Studies (MINORS) tool. The evaluation was independently carried out by two reviewers (A.B. and M.D.), with any discrepancies resolved through consultation with a third author (A.A.).

The twelve items of the MINORS tool used for this assessment are listed in Table A2 [19].

Data collection was considered appropriate when a clearly defined and consistently followed study protocol was reported; in the absence of such details, it was considered partially appropriate. Outcome measurement was deemed adequate when the study provided a clear and explicit description of the criteria used to assess the results. Follow-up

was judged appropriate when it extended beyond one year. Each study was scored based on these predefined criteria, contributing to the final MINORS quality rating.

When necessary, missing data were retrieved by contacting the corresponding authors of the included studies. In cases where no response was obtained, data were handled in accordance with the recommendations provided by the Cochrane Handbook for Systematic Reviews of Interventions.

2.8. Data Synthesis and Statistical Analysis

All extracted data were synthesized, and a comprehensive qualitative summary was provided based on the predetermined outcomes of this review. For the quantitative analysis, pooled mean differences (MDs) and corresponding 95% confidence intervals (CIs) were calculated for continuous variables, including overbite, SN-GoMe angle, FMA, ANB, SN-Pog, and N-Me.

A random-effects model was applied to account for clinical and methodological heterogeneity. Heterogeneity was assessed using the I^2 statistic, with values >50% considered indicative of substantial heterogeneity. When meta-analysis was not feasible due to high heterogeneity or lack of comparable data, a narrative synthesis was performed. Inter-reviewer agreement for study selection and risk of bias assessment was measured using Cohen's Kappa coefficient. The meta-analyses were conducted using Review Manager software (RevMan, version 5.4.1; The Cochrane Collaboration, Copenhagen, Denmark). Statistical significance for pooled estimates was inferred when the 95% CI did not include zero. Only studies including patients aged ≥18 years and with a minimum of 6 months post-retention follow-up were included in the meta-analysis.

3. Results

3.1. Study Selection

A total of 1891 records were identified through both electronic (n = 1889) and manual (n = 2) searches. The number of records retrieved from each database is reported in Table A1. After removing duplicates, titles and abstracts were screened for relevance, resulting in 32 articles selected for full-text evaluation. Following assessment against the predefined inclusion and exclusion criteria, 22 studies were included in the qualitative synthesis with a sample age limit ≥12 years and with permanent dentition.

All included articles were written in English. Only studies involving adult patients (≥18 years) and reporting a minimum of 6 months of post-retention follow-up were considered suitable for quantitative analysis. Consequently, five studies were included in the meta-analysis. Excellent inter-reviewer agreement was observed during the study selection process ($\kappa = 0.95$). A flow diagram summarizing the selection process is shown in Figure 1.

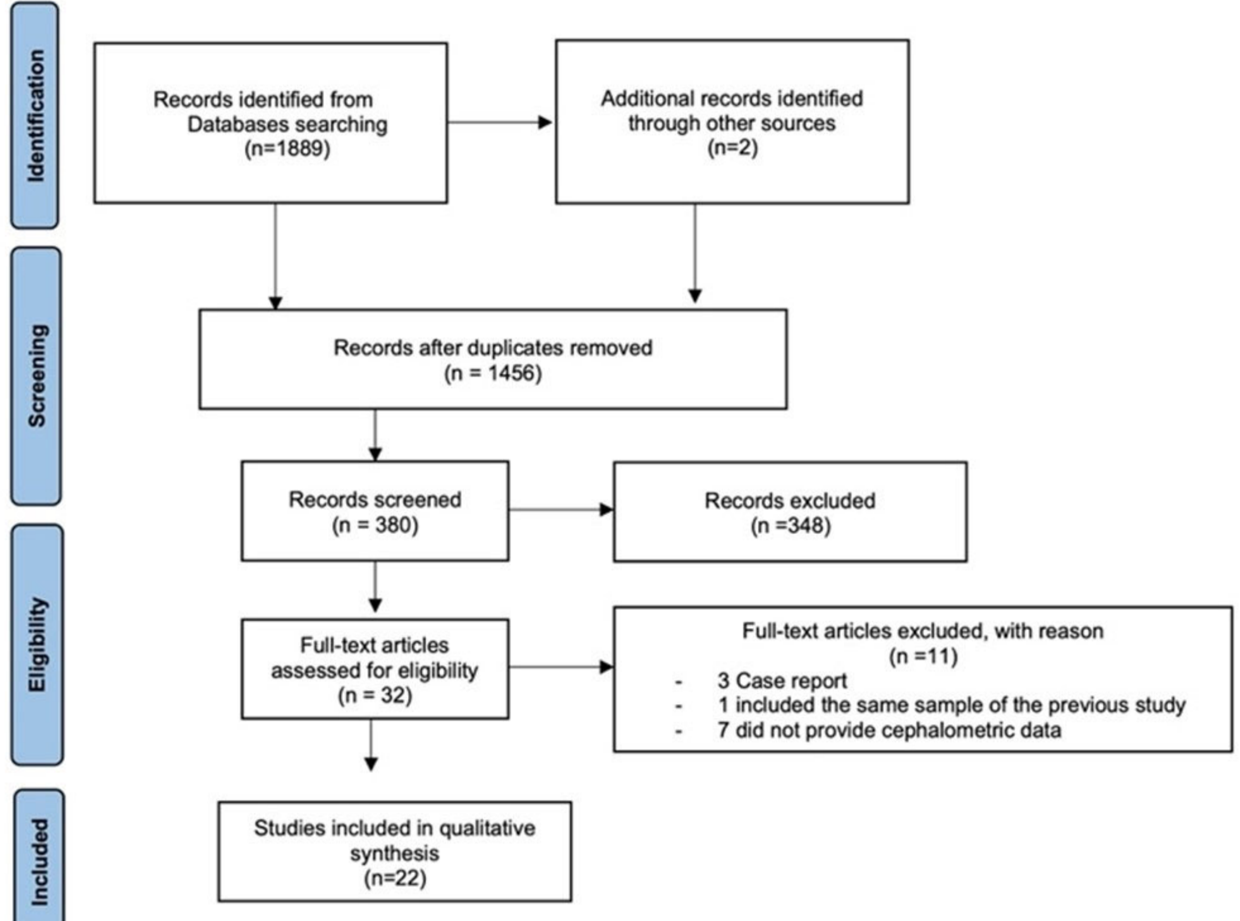

Figure 1. PRISMA 2020 flow diagram illustrates the number of records identified, screened, and excluded at each stage of the review process.

3.2. Characteristics of the Studies

Of the included studies, one was a randomized controlled trial (RCT), twelve were prospective studies (including two with a control group), and eight were retrospective studies (including one with a control group).

A summary of the main characteristics of the included studies is provided in Tables 2 and 3, reporting the following information: authors and year of publication, study design, type of assessment, sample size, mean age of participants, gender distribution, treatment duration, measurement methods, devices used, force applied, maxillary and/or mandibular site of skeletal anchorage application, follow-up period, reduction in anterior open bite, effect on mandibular autorotation, changes in cephalometric variables (overbite, ANB, N-Me, SN-GoMe, SN-Pog, FMA), and other assessed outcomes.

Table 2. Summary of the main characteristics of the included studies (Part 1 of 2).

Author and Year of Publication	Study Design	Comparison	Sample Size	Age	Gender Distribution	Treatment Time	Method of Measurement	Devices Used	Force Applied	Maxillary or Mandibular Application of Devices	Follow Up
Sugawara et al. (2002) [20]	Retrospective Study	T0 (Pre-treatment) T1 (Treated with miniplates)	9 patients	13.3 to 28.9 years (Mean 21.1)	2 males 7 females	9 to 22 months (Average 14.9 months)	Dental cast analysis Panoramic analysis Lateral cephalometric analysis	L-shaped Miniplates	Not available	Mandibular	12 months
Sherwood et al. (2002) [21]	Retrospective Study	T0 (Pre-treatment) T1 (Treated with miniplates)	4 adult patients	NR *	2 men 2 women	5.5 months (Mean)	Lateral cephalometric analysis Panoramic radiographs	Miniplates	Not available	Maxillary and mandibular	NR *
Erverdi et al. (2004) [22]	Prospective Study	T0 (Pre-treatment) T1 (Treated with miniplates)	10 patients	17–23 years		5.1 months	PA radiograph analysis Lateral cephalometric analysis	I-shaped-miniplates Sectional wire in upper posterior segment	Not available	Maxillary	NR *
Erverdi et al. (2007) [23]	Prospective Longitudinal Study	T0 (Pre-treatment) T1 (Treated with miniplate and acrylic plates)	11 patients	19.5 years (mean)	5 males 6 females	9.6 months	Lateral cephalometric analysis	I-shaped miniplates in upper posterior segment	400 g per side	Maxillary	NR *
Xun et al. (2007) [24]	Retrospective Study	T0 (Pre-treatment) T1 (Treated with miniscrews)	12 patients	18.7 years (mean)		6.8 months	Lateral cephalometric analysis	Midpalatal miniscrew in upper arch Buccal miniscrews in lower molars	150 g per side	Maxillary and mandibular	NR *
Kuroda et al. (2007) [15]	Prospective Clinical Trial	Comparison of two groups G1: treated with miniplates or miniscrews G2: Treated with orthognathic surgery	10 patients (G1) 13 patients (G2)	16–46 years 21.6 years (Mean)	4 males 9 females	G1: 19–36 months (27.6 months average) G2: 20–44 months (33.5 months average)	Lateral cephalometric analysis	G1: TADs sectional wire in upper and lower posterior segment G2: LeFort 1 osteotomy and intraoral vertical ramus osteotomy or sagittal split ramus osteotomy	G1: 150 g G2: Not declared	Maxillary and mandibular	NR *
Lee HA, and Park YC (2008) [25]	Prospective Longitudinal study	Pre-treatment group and post-treatment group treated with miniscrews	11 patients	18.2–31.1 years 23.3 years (mean)	1 male 10 females	5.4 months	Lateral cephalometric analysis	Miniscrews placed buccally in the upper jaw with a splint to prevent molar tipping and a sectional wire in upper posterior segment	Not available	Maxillary	17.4 months
Seres and Kocsis (2009) [26]	Retrospective study	Pre-treatment group and post-treatment group treated with miniplates only	7 patients	15–29 years (mean 21)	3 males 4 females	6 months (Mean)	Lateral cephalometric analysis Posteroanterior cephalometric analysis Orthopantomograms Periapical radiographs	Miniplates Coil Springs	100–120 g per side	Maxillary	NR *
Baek et al. (2010) [27]	Retrospective Study	Pre-treatment group and post-treatment group treated with miniscrew implants only	9 patients	18.3–31.1 years (Mean 23.7 years)	8 women 1 man	Mean treatment time 5.4 months Mean retention period 41 months (range 36–51 months)	Lateral cephalometric analysis	Miniscrew implants Elastomeric chains Rigid transpalatal arches	NA	Maxillary	3 years
Buschang et al. (2011) [28]	Prospective study	Pre-treatment group and post-treatment group treated with miniscrews	9 patients	13.2 years (mean)	1 male 8 females	1.4 to 2.5 years (average 1.9 years)	Lateral cephalometric analysis	MSIs miniscrews implants in upper molars associated with RPE MSI in lower molars	150 g per side	Maxillary and mandibular	NR *
Deguchi et al. (2011) [29]	Retrospective Longitudinal Clinical Trial	Comparison of two groups: G1 (non-implant) treated with anterior elastics, high-pull headgear, and MEAW G2 (implant) treated with skeletal anchorage	G1: 15 patients G2: 15 patients	G1: 22.9 ± 0.9 years G2: 25.7 ± 6.4 years	15 females G1 15 females G2	G1: 1–3 years G2: 1–3 years	Cast analysis PAR and DI scores Lateral cephalometric analysis	G1: High-pull headgear; MEAW; Elastics G2: Mini-implants	Not available		24 months
Akan et al. (2013) [30]	Prospective study	Pre-treatment group and post-treatment group treated with miniplates and acrylic plates	19 patients	17.7 years (mean)	6 males 13 females	6.8 months	PA Radiograph EMG and EVG recording Lateral cephalometric analysis	Miniplates in upper molars	400 g per side	Maxillary	NR *
Scheffler et al. (2014) [31]	Retrospective Longitudinal study	Pre-treatment group and post-treatment group treated with miniplates and miniscrews and acrylic plates	30 patients	12.7 to 48.1 years 24.1 years (mean)	11 males 19 females	3.6–9.6 months for intrusion 6–33 months total treatment time	Lateral cephalometric analysis	Miniscrews (16 patients) Miniplates (14 patients) Acrylic plates	150 g per side	Maxillary	More than 2 years
Foot et al. (2014) [32]	Prospective study	Pre-treatment group and post-treatment group treated with miniscrews and acrylic plates	16 patients	12.2 to 14.3 years 13.1 (Mean)	4 males 12 females	2.5 to 7.7 months (average 4.91 months)	Cone beam Lateral cephalometric analysis	Sydney intrusion spring in upper posterior segment	500 g per side	Maxillary	NR *

Table 2. *Cont.*

Author and Year of Publication	Study Design	Comparison	Sample Size	Age	Gender Distribution	Treatment Time	Method of Measurement	Devices Used	Force Applied	Maxillary or Mandibular Application of Devices	Follow Up
De Oliveira et al. (2014) [33]	Prospective study	Pre-treatment group and post-treatment group treated with miniplates	9 patients	18.7 ± 5.1 years (Mean)	6 females 3 males	6 months approximately	Lateral and oblique cephalometric analysis	Miniplates and transpalatal arches	450–500 g per side on each molar	Maxillary	NR *
Hart et al. (2015) [34]	Retrospective study	Pre-treatment group and post-treatment group treated with palatal miniscrews	31 patients: 21 adolescents 10 adult patients	12.6 to 55.5 years 20.7 years (mean)	10 males 21 females	1.3 years	Lateral cephalometric analysis	Bilateral perimolar palatal miniscrew (25p) and midpalatal mini-implants (6) in upper arch	Not declared	Maxillary	NR *
Marzouk et al. (2015) [35]	Prospective study	Pre-treatment group and post-treatment group treated with miniplates	13 patients	16 years 2 months–22 years 9 months (mean age 18 years, 8 months ± 2 years, 2 months)	9 females 4 males	9 months ± 2.5 months	Lateral and postero-anterior cephalometric analysis	Miniplates in association with a double TPA and NiTi coil springs	450 g per side	Maxillary	NR *
Marzouk and Kassem (2016) [36]	Prospective study	Pre-treatment group and post-treatment group treated with miniplates only	26 patients	19 years 4 months –26 years 11 months (22 years 5 months mean)	15 women 11 men	24–28 months (mean 26.2 months)	Lateral cephalometric analysis	Miniplates	150 g per molar 75 g per premolar per side	Maxillary	4 years
Turkkahra man and Sarioglu (2016) [12]	Prospective study Controlled trial	Treatment group with miniplates and control group	Treatment group (TG): 20 patients Control group (CG): 20 patients	TG: 16.68 ± 2.8 years CG: 16.63 ± 2.83 years	TG: 14 females 6 males CG: 11 females 9 males	TG: 1 ± 0.31 years CG: 0.95 ± 0.14 years	Lateral cephalometric analysis Dental cast analysis Total and local structural superimposition method of Björk and Skieller	Miniplates and a rigid hyrax appliance NiTi coil springs	200 g on the posterior teeth	Maxillary	NR *
Akl et al. (2020) [37]	Randomized controlled trial	Treatment group with 400 g force application and control group with 200 g force application	Treatment group (TG): 11 patients Control group (CG): 11 patients	Control 19.22 ± 1.45 years Intervention 18.95 ± 1.77 years	NA	6 months	CBCT	Miniscrews Closed Ni-Ti Coil Spring	200 g for the comparator group 400 g for the interven-tion group	Maxillary	NR *
Akbaydogan and Akin (2021) [38]	Prospective study	Pre-treatment group and post- treatment group treated with miniscrews and maxillary occlusal splints	20 patients	14.71 ± 1.77 years	14 females 6 males	8 months	Lateral cephalometric analysis	Palatal miniscrews Elastic chains Acylic plates	250 g per side	Maxillary	NR *
Akl et al. (2025) [39]	Randomized controlled clinical trial	Two groups: G1 treated with 400 g force application vs. G2 treated with 200 g force application	G1: 20 patients—G2: 20 patients	Mean 19.8 ± 2.4 years	27 females, 13 males	3 years post-treatment	Lateral cephalometric radiographs before treatment, after intrusion, and at 6-month follow-up	Titanium miniscrews with intrusion mechanics	200 g or 400 g per side	Maxillary posterior teeth	6 months post-treatment

* NR = Not reported.

Table 3. Summary of the main characteristics of the included studies (Part 2 of 2).

Author and Year of Publication	Reduction in Open Bite	Effect on Mandibular Autorotation	Effect on Cephalometric Variables	Outcomes Assessed
Sugawara et al. (2002) [20]	Increase in overbite by 4.9 mm	Counterclockwise rotation of the mandible Reduction in FH/MP by 1.3°	Reduction in ALFH Reduction in interlabial gap Improvement of AP jaw relations Stable profile after 1 year SNA reduction SNB increase ANB reduction	Overbite MP/FH LAFH U6-PP L6-MP SNA SNB ANB
Sherwood et al. (2002) [21]	Overbite increased by 3–4.5 mm (3.62 mm mean)	Counterclockwise rotation of the mandible SN-MP reduction SN-OP reduction N-S-Gn reduction	N-Me reduction Reduction in AFH Increase in SNB Reduction in N-S-Gn	Overbite SN-MP SN-OP N-S-Gn N-Me SNB
Erverdi et al. (2004) [22]	Increase in overbite by 3.7 mm	Reduction in Go Gn/SN by 1.7° Counterclockwise rotation of the mandible	Reduction in AFH Increase in glabella- SN-Pog Improvement of smile and profile SNA increase SNB increase ANB reduction	Overbite GoGn/SN U6-PP L6-MP SNA SNB ANB
Erverdi et al. (2007) [23]	Increase in overbite by 5.1 mm	Reduction in Go Gn/SN by 3° Counterclockwise rotation of the mandible	Reduction in LAFH Increase in SNA Increase in SNB Reduction in ANB	Overbite GoGn/SN LAFH U6-PP SNA SNB ANB
Xun et al. (2007) [24]	Increase in overbite by 4.2 mm	Reduction in Me Go/SN by 2.3° Counterclockwise rotation of the mandible	Reduction in AFH Reduction in LAFH Reduction in Ns-Sn-Pos Improvement of convex profile SNA Reduction SNB Increase ANB Reduction	Overbite MeGo/SN LAFH U6-PP L6-MP SNA SNB ANB
Kuroda et al. (2007) [15]	G1: Increase in overbite by 6.8 mm G2: Increase in overbite by 7 mm	G1: Counterclockwise rotation of the mandible Reduction in FH/MP by 3.3° G2: Counterclockwise rotation of the mandible Reduction in FH/MP by 0.3°	G1: Reduction in TAFH and LAFH Overall better facial improvement than with surgery G2: Reduction in TAFH LAFH unchanged	Overbite MP/FH LAFH U6-PP L6-MP SNA SNB ANB
Lee HA, and Park YC (2008) [25]	Increase in overbite by 5.47 mm	Counterclockwise rotation of the mandible Reduction in Me Go/SN by 1.99° Increase of by 0.9°	Reduction in AFH Forward shift in pogonion by 2.17 mm Esthetic improvement of overall facial appearance Increase in AFH by 0.38 mm after 17.4 month of retention Increase in SNB Reduction in ANB	Overbite MeGo/SN SN-Pog MP/FH AFH U6-PP SNB ANB FMA
Seres and Kocsis (2009) [26]	Complete correction	Autorotoation of the mandible The mandibular plane closed by an average of 3.1° Point B rotated anteriorly and upwards	AFH decreased Facial profile improved significantly	AFH Facial profile Mandible rotation Mandibular plane angle Point B position

Table 3. *Cont.*

Author and Year of Publication	Reduction in Open Bite	Effect on Mandibular Autorotation	Effect on Cephalometric Variables	Outcomes Assessed
Baek et al. (2010) [27]	5.56 ± 1.94 mm	Counterclockwise rotation of the mandible SN-GoMe reduction by 2.03° SN-Pog Increase by 1.1°	AFH reduction ANB reduction FMA reduction Forward and upward movement of point B and Po	SN-GoMe SN-Pog FMA AFH Overbite IMPA U6-PP ANB
Buschang et al. (2011) [28]	Not declared	Reduction in MPA by 3.9° Counterclockwise rotation of the mandible	Chin moved forward by 2.4 mm Increase in SNB Reduction in facial convexity	MPA SNB
Deguchi et al. (2011) [29]	G1: Increase in overbite by 6.5 mm G2: Increase of overbite by 6.2 mm	G1: Increase in MP/SN by 2.7° Clockwise rotation of the mandible G2: Reduction in MP/SN by 3.6° Counterclockwise rotation of the mandible	G1: Increase in AFH and reduction in facial convexity and lips protrusion G2: Reduction in AFH reduction in facial convexity (more than G1) and reduction in lips protursion Disappearance of incompetent lips	Overbite MeGo/SN LAFH U6-PP L6-MP SNA SNB ANB
Akan et al. (2013) [30]	Increase in overbite by 4.79 mm	Reduction in Go Gn/SN by 3.79° Counterclockwise rotation of the mandible	Increase in SNB Reduction in LAFH Reduction in AFH Reduction in facial convexity Increase in upper lip/E plane SNA Reduction SNB Increase ANB Reduction	Overbite MP/FH GoGn/SN LAFH U6-HL L6-MP SNA SNB ANB
Scheffler et al. (2014) [31]	Increase in overbite by 2.2 mm	Reduction in Go Gn/SN by 1.2° Counterclockwise rotation of the mandible	Reduction in LAFH	Overbite GoGn/SN
Foot et al. (2014) [32]	Overbite increase by 3 mm	Reduction in MP/SN by 1.2° Counterclockwise rotation of the mandible	Reduction in LAFH Reduction in G′SnPo′ Increase in SNA Increase in SNB Reduction in ANB	Overbite MP/FH MMA GoGn/SN LAFH U6-PP L6-MP SNA SNB ANB
De Oliveira et al. (2014) [33]	NA	Counterclockwise rotation of the mandible (1.57°) The occlusal plane showed a clockwise rotation of 4.27° SN-GoMe reduction by 1.57°	N-Me reduction PFH unchanged SNˆANS-PNS reduction SN-GoMe reduction SNˆMcUIi increase	N-Me SNˆGoMe OcPl angle
Hart et al. (2015) [34]	Increase in overbite by 3.8 mm	Reduction in FH/MP by 1.1° Counterclockwise rotation of the mandible	Reduction in LAFH Reduction in AFH Reduction in PFH Reduction in SNA Increase in SNB Reduction in ANB	Overbite MP/FH LAFH U6-PP U6-BaH L6-MP SNA SNB ANB

Table 3. *Cont.*

Author and Year of Publication	Reduction in Open Bite	Effect on Mandibular Autorotation	Effect on Cephalometric Variables	Outcomes Assessed
Marzouk et al. (2015) [35]	6.55 ± 1.83 mm	Counterclockwise rotation of the mandible MP-SN decrease by 1.6° SN-Pog increase by 1.6° Increase in L1-FHP angle by 1.4° Increase in interincisal angle by 3.7°	SNB increase ANB decrease N-S-Gn decrease N-A-Pog decrease N-Me reduction ANS-Me reduction SN-OP increase N′-Sn-Pog′ reduction Interincisal angle increase Improvement in facial soft tissue convexity Overjet reduction Forward and upward displacement of B point and pogonion Reduction in mandibular plane angle	N-Me ANS-Me MP-SN angle SN-Pog N-S-Gn angle U6 to PP OP-SN Overbite Interincisal angle Soft tissue facial convexity N′-Sn-Pog′ angle SNB ANB
Marzouk and Kassem (2016) [36]	6.93 mm SD1.99 mm	Counterclockwise rotation of the mandible SN-MP Reduction SN-Pog Increase N-S-Gn Reduction	AFH reduction SNA reduction SNB increase ANB reduction MMA reduction Forward and upward movement of point B and Po Reduction in facial convexity Improvement in the patient's appearance	Overbite AFH LAFH Convexity angle SN-Mp SN-Pog N-S-Gn U6-PP L6-MP N′-Sn-Pog′ SNA SNB ANB
Turkkahra man and Sarioglu (2016) [12]	4.82 ± 1.53 mm	Counteclockwise rotation of the mandible Posterior rotation of the occlusal plane Reduction in SN/GoGn by 2.25° Increase in SN/OccP by 3.42°	TAFH Reduction LAFH Reduction Upward and forward movement of the chin Improvement of maxillary-mandibular discrepancy Anterior rotation of the mandible Increase in intermolar width Increase in interpremolar width	SN/GoGn Overbite SN/OccP N-Me S-Go/N-Me
Akl et al. (2020) [37]	Treatment group 5.75 ± 1.87 mm Comparator group 5.01 ± 0.93 mm	Counterclockwise rotation of posterior segment		UR4/FH-UR4/MSP UR5/FH-UR5/MSP UR6/FH-UR6/MSP UR7/FH-UR7/MSP UL4/FH-UL4/MSP UL5/FH-UL5/MSP UL6/FH-UL6/MSP UL7/FH-UL7/MSP UR/FH-UR/MSP UL/FH-UL/MSP LR4 center-MP LR5 center-MP LR6 fur-MP LR7 fur-MP LL4 center-MP LL5 center-MP LL6 fur-MP LL7 fur-MP
Akbaydogan and Akin (2021) [38]	Overbite increased by 5.81 ± 0.97 mm	Counterclockwise rotation SN/GoGn decreased by 2.7°	AFH reduction LAFH reduction Midfacial height reduction Convexity angle reduction SNA Reduction SNB Increase ANB Reduction	Overbite AFH LAFH Midfacial height Convexity Angle SNA SNB ANB

Table 3. *Cont.*

Author and Year of Publication	Reduction in Open Bite	Effect on Mandibular Autorotation	Effect on Cephalometric Variables	Outcomes Assessed
Akl et al. (2025) [39]	Significant overbite increase in both groups, greater with 400 g	Counterclockwise mandibular rotation in both groups	Significant changes in SNA, SNB, ANB, MP/SN, LAFH; greater effects with higher force magnitude	Overbite correction, mandibular rotation, skeletal and dental positional changes, stability

3.3. Temporary Anchorage Devices—TADs

Among the included studies, 10 used miniplates as TADs, 10 used miniscrews, and one study employed both miniplates and miniscrews for orthodontic anchorage.

3.4. Assessment of Clinical Outcomes

The studies include in this systematic review measured outcomes in different ways: 10 studies used lateral cephalometric analysis [15,23–25,27,28,31,34,35,38], one study used lateral cephalometric analysis with cone beam computer tomography [32], one study used lateral cephalometric analysis with panoramic radiographies [21], one study used lateral cephalometric analysis, dental cast analysis and total and local superimpositions [30]; one study used lateral cephalometric analysis, postero-anterior cephalometric analysis, panoramic radiographies and periapical radiographies [26]; one study used lateral cephalometric analysis, dental cast analysis and panoramic radiography [20]; one study used lateral cephalometric analysis, posterior–anterior radiography, dental cast analysis and DI scores [29]; one study used lateral cephalometric analysis, postero-anterior radiographies, EMG and EVG analyses [30]; one study used lateral cephalometric analysis and oblique cephalometric analysis [33]; one study used lateral cephalometric analysis and postero-anterior radiography [22] and one study used CBCT [37].

3.5. Follow-Up Period

Among the included studies, one study had a post-retention follow up period of 1 year [20]; one study had post-retention follow up period of 17 months [25]; one study had post-retention follow up period of 2 years [29]; one study had a post-retention follow up period of more than 2 years [31]; one study had a post- retention follow up period of 3 years [27]; one study had a post-retention follow up period of 4 years [35].

3.6. Cephalometric Outcomes

The most frequently used evaluation method among the included studies was lateral cephalometric analysis.

3.6.1. Sagittal Measurements

To assess changes in the sagittal dimension, most studies analyzed the following angular measurements:

- SNA Angle: The angle between the Sella-Nasion (SN) plane and the Nasion-A point (NA) line, used to evaluate the anteroposterior position of the maxilla.
- SNB Angle: The angle between the SN plane and the Nasion-B point (NB) line, used to determine the sagittal position of the mandible.
- ANB Angle: Calculated as the difference between SNA and SNB angles; it is a key indicator of the skeletal sagittal relationship between the maxilla and the mandible.

3.6.2. Vertical Measurements

Vertical changes were evaluated using both linear and angular measurements:

- Overbite: The vertical linear distance between the incisal edges of the lower central incisor (L1) and the upper central incisor (U1).
- SN-GoGn: The angle between the SN plane and the Gonion-Gnathion (GoGn) plane, used to assess mandibular plane inclination.
- SN-GoMe: The angle between the SN plane and the Gonion-Menton (GoMe) plane, another indicator of mandibular plane steepness.
- SN-Pog: The angle formed by the SN plane and the facial plane (Nasion-Pogonion), evaluating chin projection in relation to the cranial base.
- N-Me: The linear distance between Nasion (N) and Menton (Me), representing total anterior facial height.
- LAFH (Lower Anterior Facial Height): Linear measurement from Anterior Nasal Spine (ANS) to Menton (Me), representing the vertical dimension of the lower face.

3.6.3. Additional Measurements

Some studies also reported:

- MMA (Maxillo-Mandibular Angle): The angle between the maxillary plane and the mandibular plane, indicating vertical skeletal divergence.
- FMA (Frankfort-Mandibular Plane Angle): The angle between the Frankfort horizontal plane and the mandibular plane (Go-Me), used as an indicator of facial growth direction.

3.7. Qualitative Assessment

Table 4 presents the methodological quality scores assigned to the included studies, encompassing both randomized and non-randomized trials. Agreement between reviewers in the quality assessment was high (K = 0.88). The items are scored 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate). The global ideal score being 16 for non-comparative studies and 24 for comparative studies. 0–10: Low-quality study; 11–15: Average quality study; 16–20: High-quality study; 21–24: Very High-quality study.

Table 4. Qualitative analysis according to MINORS criteria.

Author and Year of Publication	1. A Clear Stated Aim	2. Inclusion of Consecutive Patients	3. Prospective Collection of Data	4. Endpoints Appropriate to the Aim of the Study	5. Unbiased Assessment of the Study Endpoint	6. Follow-Up Period Appropriate	7. Loss to Follow-Up Less Than 5%	8. Prospective Calculation of the Study Size	9. An Adequate Control Group	10. Contemporary Groups	11. Baseline Equivalence of Group	12. Adequate Statistical Analysis	Total Score	Quality Score
Sugawara et al. (2002) [20]	1	0	0	2	0	2	2	0	2	0	0	2	11	Average
Sherwood et al. (2002) [21]	2	0	1	2	0	0	0	0	0	0	0	0	5	Low
Erverdi et al. (2004) [22]	2	0	0	2	0	0	0	0	0	0	0	1	5	Low
Erverdi et al. (2007) [23]	2	0	1	1	0	0	0	0	0	0	0	2	6	Low
Xun et al. (2007) [24]	2	0	1	2	0	0	0	0	0	0	0	2	6	Low
Kuroda et al. (2007) [15]	2	0	1	2	0	0	0	0	2	2	1	2	12	Average
Lee HA, and Park YC (2008) [25]	2	0	1	1	0	2	2	0	0	0	0	2	10	Low
Seres and Kocsis (2009) [26]	2	0	0	2	0	0	0	0	0	0	0	0	4	Low
Baek et al. (2010) [27]	2	0	2	2	0	2	2	0	0	0	0	2	12	Average
Buschang et al. (2011) [28]	1	2	2	1	0	0	0	0	0	0	0	0	6	Low
Deguchi et al. (2011) [29]	2	2	1	2	0	2	2	0	2	2	1	2	18	High
Akan et al. (2013) [30]	2	0	1	2	0	0	0	0	0	0	0	2	7	Low
Scheffler et al. (2014) [31]	1	2	0	2	0	2	0	0	0	0	0	2	9	Low
Foot et al. (2014) [32]	2	1	2	2	0	0	0	0	0	0	0	2	9	Low
De Oliveira et al. (2014) [33]	2	2	1	2	0	0	0	0	0	0	0	1	8	Low
Hart et al. (2015) [34]	2	2	1	2	0	0	0	0	0	0	0	1	8	Low
Marzouk et al. (2015) [35]	2	2	1	2	0	0	0	2	0	0	0	2	11	Average
Marzouk and Kassem (2016) [36]	2	2	2	2	0	2	0	2	0	0	0	2	14	Average
Turkkahra man and Sarioglu (2016) [12]	2	0	1	2	0	0	0	2	2	2	2	2	15	Average
Akl et al. (2020) [37]	2	0	2	2	2	0	0	2	2	2	2	2	18	High
Akbaydogan and Akin (2021) [38]	2	0	1	2	0	0	0	2	2	2	0	2	13	Average
Akl et al. (2025) [39]	2	2	2	2	2	2	2	2	2	2	2	2	24	Very high

Overall, twelve studies were classified as having low methodological quality, seven as moderate, and only two as high. The most recurrent shortcoming was the absence of blinded outcome assessment, which was reported in only one study, indicating a considerable risk of detection bias in the remaining investigations. Another frequent limitation was the inadequacy of control groups: although six studies included a comparator, only five met the methodological standards for adequacy, and baseline equivalence was confirmed in four of these [25,27,29,35,39]. Prospective sample size calculation was performed in just five studies, raising concerns regarding statistical power and the potential for Type II errors.

Despite these weaknesses, several methodological strengths were consistently identified. Most studies adopted appropriate and well-executed statistical analyses, with only two presenting less robust approaches. All clearly stated their research objectives and used outcome measures deemed relevant and appropriate for the study aims. In those reporting follow-up data, the observation period was considered adequate, and loss to follow-up was generally minimal, exceeding 5% in only two cases.

In summary, while the included studies share important strengths such as the use of relevant outcome measures, clearly defined research objectives, and adequate follow-up protocols, the overall quality of evidence is limited by recurring weaknesses related to blinding, control group adequacy, and sample size planning.

3.8. Quantitative Synthesis

Of the 22 studies included in the qualitative analysis, only five provided sufficient data to be considered in the meta-analysis. For these studies, mean differences and standard deviations were extracted for the following cephalometric parameters: overbite, N-Me, SN-GoMe, SN-Pog, FMA and ANB (Tables 5–7).

Table 5. T2–T1 Comparison for all the considered variables.

OVERBITE			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (mm)**	**SD of Differences**
Lee HA, and Park YC (2008) [25]	11	5.47	1.28
Baek et al. (2010) [27]	9	5.56	1.235
Deguchi et al. (2011) [29]	15	6.2	1.15
Marzouk and Kassem (2016) [36]	26	6.93	1.375
Akl et al. (2025) [39]	20	3.42	1.79
ANB			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (°)**	**SD of Differences**
Lee HA, and Park YC (2008) [25]	11	−0.59	1.39
Baek et al. (2010) [27]	9	−0.66	1.42
Deguchi et al. (2011) [29]	15	−1.5	3.85
Marzouk and Kassem (2016) [36]	26	−3.84	1.12
Akl et al. (2025) [39]	20	0.05	1.74
N-Me			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (mm)**	**SD of Differences**
Lee HA, and Park YC (2008) [25]	11	−2.64	5.61
Baek et al. (2010) [27]	9	−2.54	5.825
Deguchi et al. (2011) [29]	15	−3.6	6.7
Marzouk and Kassem (2016) [36]	26	−3.63	5.915
Akl et al. (2025) [39]	20	−1.99	4.47

Table 5. *Cont.*

FMA			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (°)**	**SD of Differences**
Lee HA, and Park YC (2008) [25]	11	−2.9	3.41
Baek et al. (2010) [27]	9	−3.15	3.665
Akl et al. (2025) [39]	20	−1.38	4.34
SN-GoMe			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (°)**	**SD of Differences**
Lee HA, and Park YC (2008) [25]	11	−1.99	4.25
Baek et al. (2010) [27]	9	−2.03	4.26
Akl et al. (2025) [39]	20	−1.03	4.43
SN-Pog			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (°)**	**SD of Differences**
Lee HA, and Park YC (2008) [25]	11	−0.23	4.39
Baek et al. (2010) [27]	9	−0.47	3.945
Marzouk and Kassem (2016) [36]	26	−0.49	2.605
Akl et al. (2025) [39]	20	−0.07	4.07

Table 6. T3–T2 Comparison for all the considered variables.

OVERBITE			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (mm)**	**SD of Differences**
Lee HA, and Park YC (2008) [25]	11	−0.98	0.745
Baek et al. (2010) [27]	9	−0.99	0.805
Deguchi et al. (2011) [29]	15	−0.8	0.1
Marzouk and Kassem (2016) [36]	26	−0.57	0.45
Akl et al. (2025) [39]	20	−0.35	1.79
ANB			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (°)**	**SD of Differences**
Lee HA, and Park YC (2008) [25]	11	0	1.425
Baek et al. (2010) [27]	9	0	1.555
Deguchi et al. (2011) [29]	15	0.1	0.05
Marzouk and Kassem (2016) [36]	26	0.33	1.125
Akl et al. (2025) [39]	20	0.05	1.74
N-Me			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (mm)**	**SD of Differences**
Lee HA, and Park YC (2008) [25]	11	0.38	5.59
Baek et al. (2010) [27]	9	0.45	5.82
Deguchi et al. (2011) [29]	15	0.2	0.1
Marzouk and Kassem (2016) [36]	26	0.56	5.725
Akl et al. (2025) [39]	20	0.19	4.56

Table 6. *Cont.*

FMA			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (°)**	**SD of Differences**
Lee HA, and Park YC (2008) [25]	11	0.91	3.755
Baek et al. (2010) [27]	9	0.63	3.995
Akl et al. (2025) [39]	20	0.10	4.83
SN-GoMe			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (°)**	**SD of Differences**
Lee HA, and Park YC (2008) [25]	11	0.18	4.7
Baek et al. (2010) [27]	9	0.27	4.645
Akl et al. (2025) [39]	20	0.11	4.43
SN-Pog			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (°)**	**SD of Differences**
Lee HA, and Park YC (2008) [25]	11	0.9	4.05
Baek et al. (2010) [27]	9	1.1	3.68
Marzouk and Kassem (2016) [36]	26	2.32	2.665
Akl et al. (2025) [39]	20	0.94	4.07

Table 7. T4–T2 Comparison for all the considered variables.

OVERBITE			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (mm)**	**SD of Differences**
Baek et al. (2010) [27]	9	−1.2	0.955
Marzouk and Kassem (2016) [36]	26	−0.77	0.435
Akl et al. (2025) [39]	20	−0.37	1.79
ANB			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (°)**	**SD of Differences**
Baek et al. (2010) [27]	9	0.17	1.615
Marzouk and Kassem (2016) [36]	26	0.61	1.13
Akl et al. (2025) [39]	20	0.04	1.74
N-Me			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (mm)**	**SD of Differences**
Baek et al. (2010) [27]	9	0.91	5.985
Marzouk and Kassem (2016) [36]	26	1.06	5.725
Akl et al. (2025) [39]	20	0.23	4.56
SN-Pog			
Author (Year)	**Patient Sample**	**Mean Difference (After-Before) (°)**	**SD of Differences**
Baek et al. (2010) [27]	9	−0.87	3.915
Marzouk and Kassem (2016) [36]	26	−0.83	2.63
Akl et al. (2025) [39]	20	−0.08	4.07

Changes were assessed for three-time intervals: T2–T1 (post-treatment vs. pre-treatment), T3–T2 (1-year post-treatment vs. post-treatment), and T4–T2 (≥3 years post-treatment vs. post-treatment), as illustrated in the forest plots in Figures 2–7.

ANB

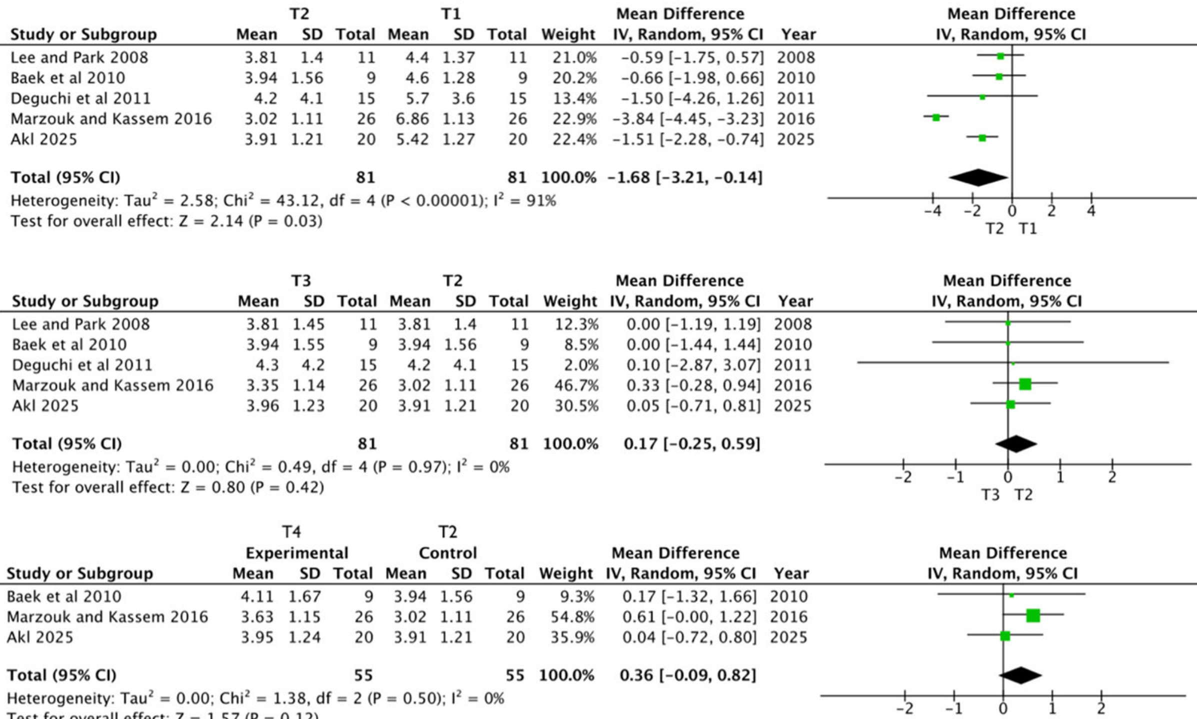

Figure 2. Forest plot on changes in ANB angle at different evaluation times (T1–T4). The mean differences with 95% confidence intervals are shown for each included study, along with the overall estimates obtained using a random-effects model [25,27,29,36,39].

FMA

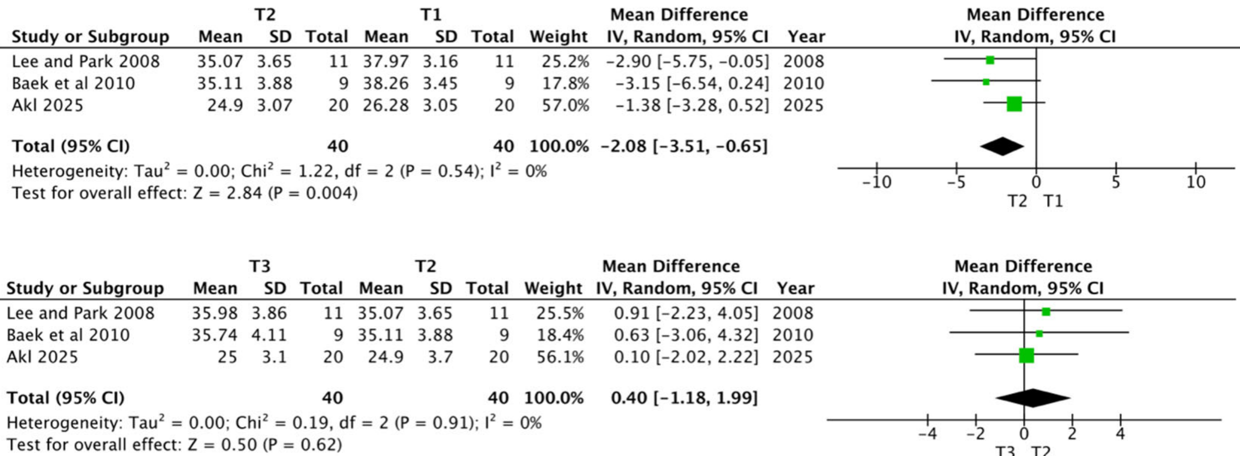

Figure 3. Forest plot on changes in FMA angle at different evaluation times (T1–T3). The mean differences with 95% confidence intervals are shown for each included study, along with the overall estimates obtained using a random-effects model [25,27,39].

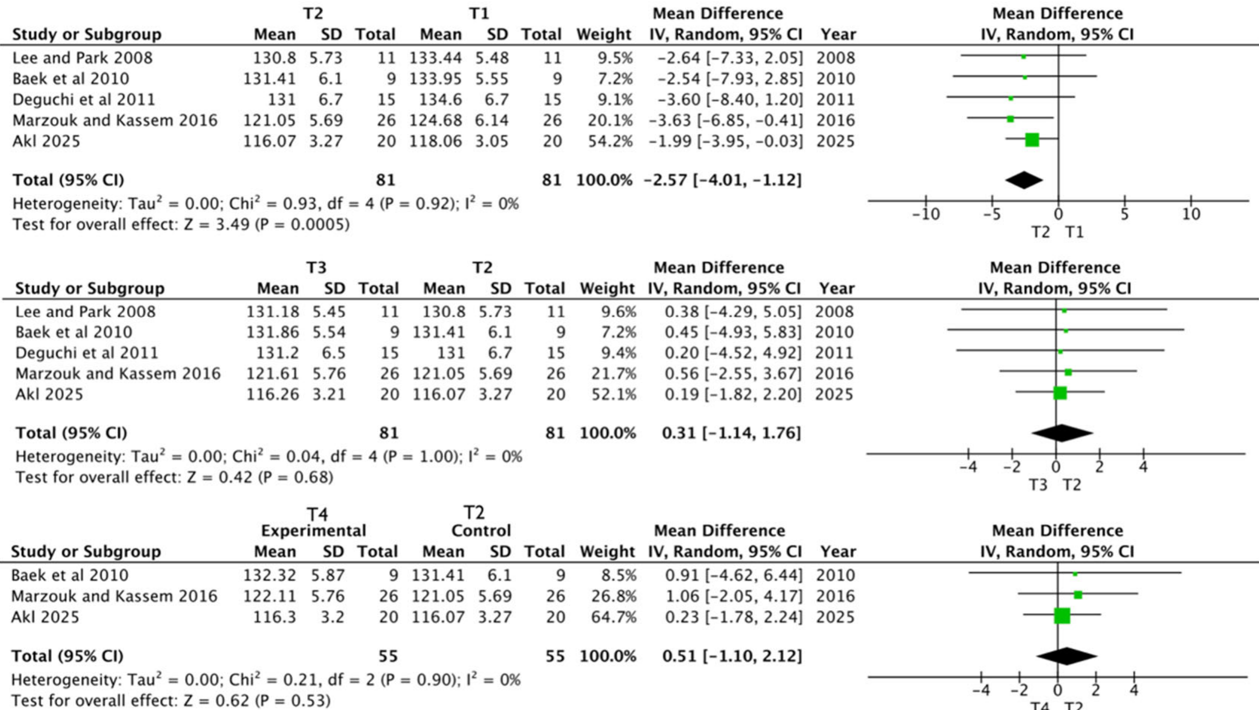

Figure 4. Forest plot on changes in N-Me distance at different evaluation times (T1–T4). The mean differences with 95% confidence intervals are shown for each included study, along with the overall estimates obtained using a random-effects model [25,27,29,36,39].

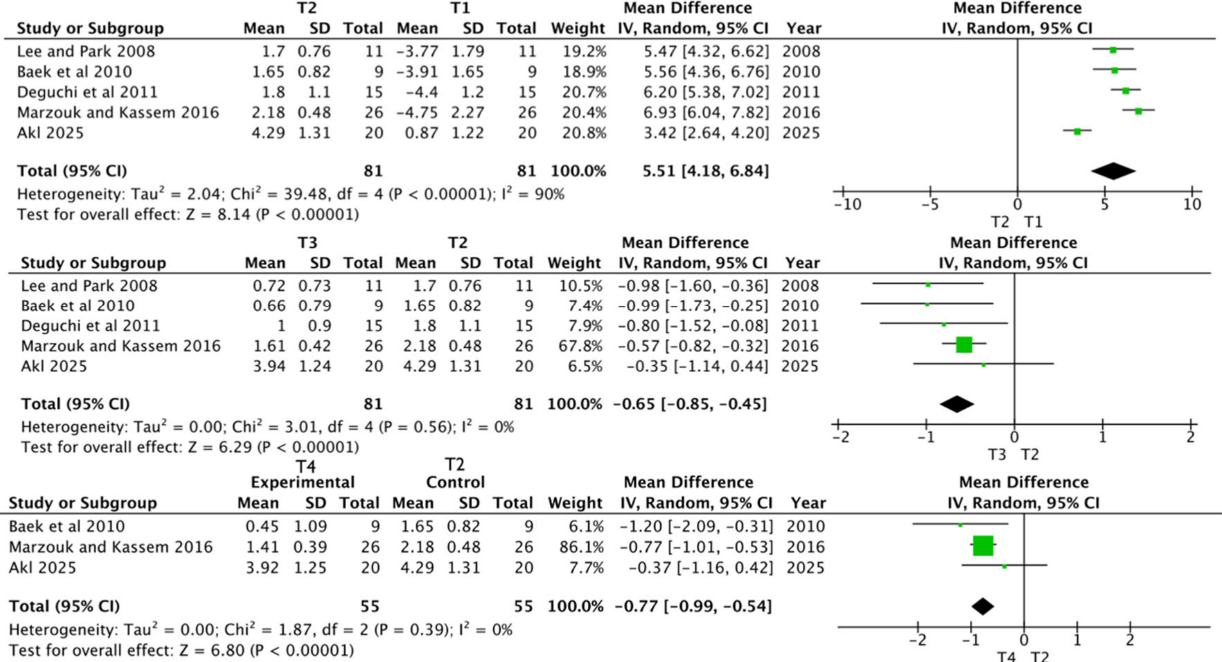

Figure 5. Forest plot on changes in Overbite at different evaluation times (T1–T4). The mean differences with 95% confidence intervals are shown for each included study, along with the overall estimates obtained using a random-effects model [25,27,29,36,39].

SN-GoMe

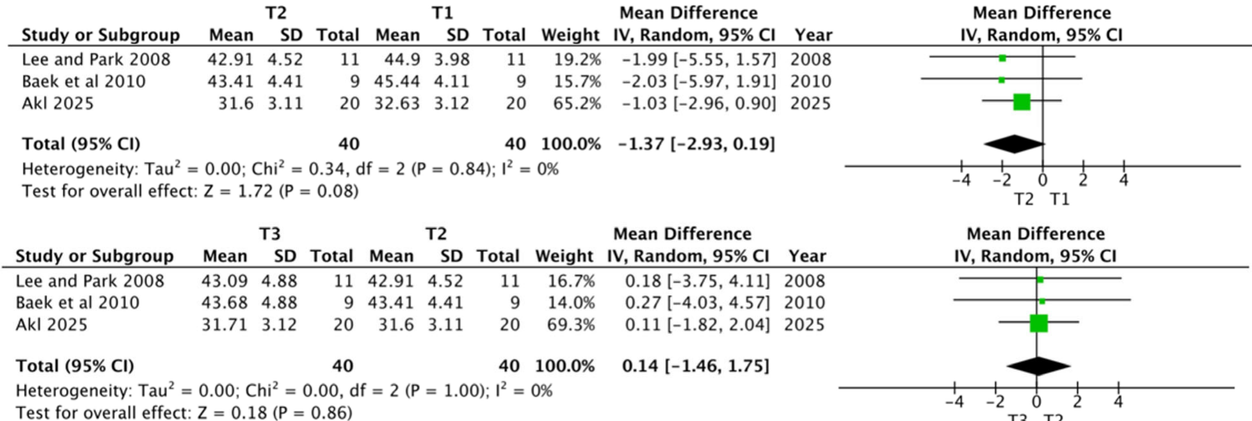

Figure 6. Forest plot on changes in SN-GoMe angle at different evaluation times (T1–T3). The mean differences with 95% confidence intervals are shown for each included study, along with the overall estimates obtained using a random-effects model [25,27,39].

SN-Pog

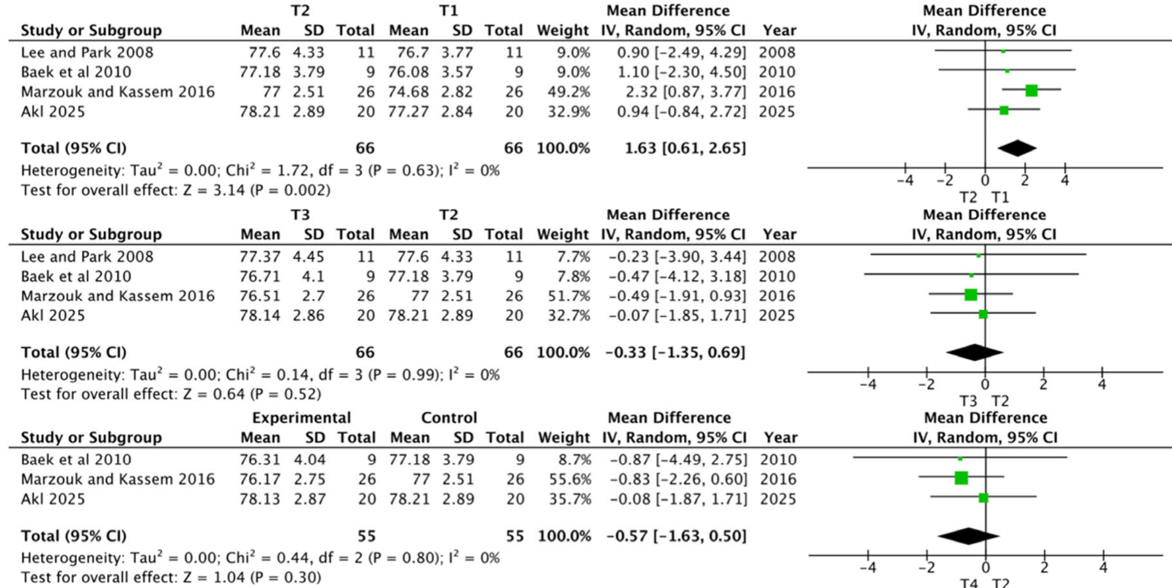

Figure 7. Forest plot on changes in SN-Pog angle at different evaluation times (T1–T3). The mean differences with 95% confidence intervals are shown for each included study, along with the overall estimates obtained using a random-effects model [25,27,36,39].

3.8.1. Short-Term Outcomes (T2–T1)

In the pre- and post-treatment comparison (T2–T1), overbite, N-Me and ANB were reported in all five studies. Overbite showed a mean increase of 5.64 mm (95% CI: 4.80 to 6.48 mm), N-Me decreased by −2.77 mm (95% CI: −4.15 to −1.39 mm) and ANB decreased by −1.72° (95% CI: −2.38° to −1.06°). SN-Pog, reported in four studies, showed a mean increase of 1.45° (95% CI: 0.52° to 2.38°). FMA and SN-GoMe, each reported in three studies, showed mean reductions in −2.17° (95% CI: −3.71° to −0.63°) and −1.64° (95% CI: −3.08° to −0.20°), respectively. In the short term, significant overbite improvement and mandibular counterclockwise rotation were observed, accompanied by reductions in

vertical parameters (FMA and SN-GoMe). These findings indicate that TAD-supported molar intrusion effectively promotes skeletal vertical control.

3.8.2. Medium-Term Outcomes (T3–T2)

In the T3–T2 interval, overbite relapse averaged −0.54 mm (95% CI: −0.76 to −0.32 mm), N-Me increased by 0.38 mm (95% CI: −1.20 to 1.96 mm), FMA increased by 0.65° (95% CI: −1.02° to 2.32°), SN-GoMe increased by 0.18° (95% CI: −1.54° to 1.90°), SN-Pog decreased by −0.39° (95% CI: −1.38° to 0.60°), and ANB increased by 0.19° (95% CI: −0.22° to 0.60°). At one-year follow-up, only modest relapse was detected, particularly in vertical measures, suggesting good stability of sagittal corrections.

3.8.3. Long-Term Outcomes (T4–T2)

In the long-term T4–T2 comparison, overbite relapse was −0.76 mm (95% CI: −1.01 to −0.51 mm), N-Me increased by 0.94 mm (95% CI: −0.80 to 2.68 mm), SN-Pog decreased by −0.79° (95% CI: −1.86° to 0.28°), and ANB increased by 0.52° (95% CI: −0.02° to 1.06°).

Overall, the meta-analysis confirmed a substantial improvement in overbite and favorable skeletal modifications immediately after treatment, followed by a modest relapse over time, more evident in vertical parameters.

3.9. Stability

Longitudinal follow-up data of up to three years indicated a generally minimal relapse for overbite, typically between 9% (at T3) and 13% (at T4).

4. Discussion

The correction of anterior open bite (AOB) in non-growing patients remains a considerable challenge in orthodontics, largely because of its multifactorial etiology and the high risk of relapse. This condition often results from a complex interplay of skeletal, dental, functional, and behavioral factors, making its management particularly demanding.

TAD-assisted molar intrusion has emerged as an effective strategy to achieve vertical control in AOB treatment without resorting to surgical intervention or relying heavily on patient compliance. Intrusion of the posterior teeth promotes counterclockwise mandibular autorotation, reduces lower anterior facial height (LAFH), and increases overbite, thereby enhancing both functional stability and facial esthetics. The present systematic review and meta-analysis sought to synthesize current evidence by specifically evaluating cephalometric skeletal changes and post-treatment stability in adult patients (≥18 years), thereby reducing potential confounding from residual growth. By examining parameters such as overbite, N-Me, FMA, SN-GoMe, and ANB angle at multiple time points (pre-treatment, post-treatment, and 1–3 years post-retention), this review offers a detailed appraisal of the skeletal effects and long-term relapse patterns following molar intrusion with skeletal anchorage.

4.1. Effects of Molar Intrusion with TADs

Across the 22 included studies, adult and adolescent patients consistently demonstrated significant overbite correction through posterior segment intrusion with TADs. Vertical changes were uniform: overbite increased significantly in all studies reporting it, and even in studies without explicit cephalometric overbite measures, AOB correction was complete.

Intrusion reduced both anterior facial height (AFH) and lower anterior facial height (LAFH) consistently, accompanied by decreases in mandibular plane angles such as SN-GoMe and FMA. Conversely, SN-Pog increased, reflecting counterclockwise mandibular autorotation. Sagittally, ANB decreased in all relevant studies, indicating mandibular advancement and improved intermaxillary relationships. These trends are corroborated by

the recent literature. A three-dimensional evaluation by Ogura et al. (2024) [9] reported maxillary molar intrusion of approximately 1.6 mm, an overbite gain of ~4.1 mm, and a 1.1° decrease in the Frankfort–mandibular plane angle, with no significant relapse after more than one year of follow-up [9]. Similarly, Chamberland & Nataf (2024) [40] compared TAD-supported double-arch intrusion with clear aligner therapy (CAT). In the TAD group, overbite increased by +4.32 mm primarily due to molar intrusion (–1.48 mm), with LAFH decreasing by 3.05 mm and SN-MPA decreasing by 1.55°, all changes remaining stable at six-month follow-up. In contrast, the CAT group achieved open bite correction (+2.33 mm) mainly via extrusion of the lower incisors (+1.22 mm), which remained stable at six months but without significant skeletal vertical changes [40].

4.2. Treatment Stability and Relapse Risk

In the adult patient populations included in our meta-analysis, skeletal anchorage for molar intrusion maintained most of vertical and sagittal corrections over follow-ups extending up to three years. Relapse at one year was generally modest, corresponding to roughly 10–15% of the overbite correction, with similar proportions for most skeletal parameters. Three-year data, although more limited, suggested no substantial additional deterioration.

Expressed in relative terms, these relapse percentages are comparable to those reported by González Espinosa et al. (2020) [6], who found mean overbite relapse of ~18% after three years, with ~80% of the change occurring in the first post-treatment year. Such values are similar to those observed after orthognathic surgery, supporting skeletal anchorage as a minimally invasive yet stable option for AOB correction in non-growing patients [6].

Interestingly, previous systematic evidence on non-skeletal-anchorage approaches shows higher relapse magnitudes. Greenlee et al. (2011) [41], in a meta-analysis of both surgical and non-surgical interventions excluding skeletal anchorage, reported weighted average overbite relapses of ~3.0 mm for orthodontic-only treatments—corresponding to 35–40% of the correction—versus ~1.4 mm (about 20%) for surgical cases, over follow-up periods ranging from 1 to 9 years. Even though their follow-up range (1–9 years) differs from ours, these data provide useful context for interpreting stability outcomes. When contrasted with our findings, these data underscore the advantage of skeletal anchorage in reducing long-term vertical rebound and improving stability without the morbidity of surgery [41].

Furthermore, the use of TADs for molar intrusion, compared with conventional approaches without skeletal anchorage, has been shown to achieve an additional mean intrusion of approximately 1.5–2.0 mm and to limit undesired incisor extrusion, which in non-TAD protocols may exceed 1 mm. This greater vertical control may help reduce relapse risk over the long term [42].

In addition, molar intrusion has direct implications for periodontal health, as treatment mechanics and appliance design may influence plaque accumulation, gingival condition, and attachment stability. Evidence from clinical studies indicates that plaque index scores can increase significantly during active intrusion—Ghanbari et al. (2015) [43] reported a mean rise from 0.62 ± 0.24 at baseline to 1.34 ± 0.36 after five months—while probing depth increased from 2.29 ± 0.36 mm to 2.74 ± 0.34 mm over the same period. These changes likely reflect the challenges of maintaining optimal hygiene around anchorage devices.

Changes in gingival margin position have also been documented: Bayani et al. (2015) [44] found an average coronal shift of 1.0 ± 0.8 mm during treatment, which remained stable during retention, along with a gain in clinical attachment level of 0.5 ± 0.7 mm. Notably, although some alveolar bone resorption occurred during active treatment, partial recovery was observed during the retention phase.Overall, these findings suggest that periodontal alterations associated with molar intrusion are generally limited and may be

at least partially reversible, but they underscore the need for strict hygiene protocols and regular periodontal monitoring throughout treatment. It is also important to note that most included studies did not evaluate long-term periodontal outcomes beyond the retention phase, leaving uncertainty about the stability of these periodontal changes over many years.

Recent literature highlights that both biomechanical control and appliance design substantially influence treatment outcomes and long-term stability. Accurate diagnosis and individualized planning—including appropriate overcorrection, precise control of force vectors, and regular periodontal assessment—are essential to reduce relapse risk. Moreover, variations in skeletal anchorage configurations, such as palatal TADs, buccal miniscrews, or double-arch mechanics, may affect not only the amount of molar intrusion achieved but also the extent of counterclockwise mandibular autorotation and the stability of these changes over time.

4.3. Limitations and Future Directions

The overall quality of the available evidence is limited. Most included studies were retrospective in nature, with only one randomized clinical trial and a small number of prospective designs. Methodological shortcomings were frequent, particularly the absence of blinded outcome assessment, inadequate or absent control groups, and the lack of prospective sample size calculations—factors that may increase the risk of bias and reduce statistical power. Heterogeneity in study protocols, retention strategies, and follow-up durations further limits comparability across studies. In addition, variability in biomechanical approaches and skeletal anchorage configurations (e.g., palatal vs. buccal TADs, single vs. double-arch mechanics) may have contributed to differences in both treatment effects and stability, but these variables were not consistently analyzed. Although the present review focused on patients aged $\geq$ 18 years to minimize growth-related confounding, residual growth—especially in late-maturing males—cannot be entirely excluded. Furthermore, most studies did not evaluate periodontal outcomes beyond the retention phase, leaving the long-term stability of these changes uncertain. Future research should prioritize high-quality randomized controlled trials or well-designed prospective cohorts, applying standardized diagnostic criteria, uniform retention protocols, and extended follow-up periods to better characterize both the magnitude and timing of relapse after molar intrusion in adult populations.

5. Conclusions

This systematic review and meta-analysis indicates that molar intrusion with TADs in adult patients reliably produces overbite closure, reductions in anterior and lower anterior facial height, mandibular counterclockwise autorotation, increases in SNB, and decreases in ANB. Quantitatively, the pooled data showed substantial immediate improvements—such as an average overbite increase of 5.64 mm—followed by only modest relapse over follow-ups of up to three years (about 0.54–0.76 mm). Stability appears generally favorable and comparable to that reported for surgical approaches, although a proportion of early relapse is common.

However, these findings should be interpreted with caution due to the predominance of non-randomized and retrospective studies, heterogeneous follow-up durations, and potential variability in biomechanical protocols. Such factors may introduce selection and measurement bias, thereby limiting the overall strength of the evidence.

Accordingly, the present synthesis provides a moderate up-to-date evidence base on the effects and stability of TAD-supported open bite correction in non-growing patients.

Future high-quality randomized controlled trials with standardized retention and follow-up protocols are needed to confirm these outcomes and better quantify relapse patterns.

From a clinical perspective, these findings support the use of slight overcorrection at treatment completion and rigorous retention protocols. Moreover, biomechanical factors, including appliance design and force-vector control, play a critical role in treatment effectiveness and stability and should be carefully considered in clinical decision-making.

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Abbreviations

The following abbreviations are used in this manuscript:

AOB	Anterior Open Bite
AFH	Anterior Facial Height
LAFH	Lower Anterior Facial Height
TAFH	Total Anterior Facial Height
TAD	Temporary Anchorage Device
MSI	Miniscrew Implant
CBCT	Cone Beam Computed Tomography
FMA	Frankfort–Mandibular Plane Angle
SN-GoMe	Sella–Nasion to Gonion–Menton Angle
SN-GoGn	Sella–Nasion to Gonion–Gnathion Angle
SN-Pog	Sella–Nasion to Pogonion Angle
SNA	Sella–Nasion to Point A Angle
SNB	Sella–Nasion to Point B Angle
ANB	Point A–Nasion–Point B Angle
N-Me	Nasion to Menton (Total Anterior Facial Height)
MMA	Maxillo–Mandibular Angle
MP/FH	Mandibular Plane to Frankfort Horizontal Angle
IMPA	Incisor–Mandibular Plane Angle
U6–PP	Upper First Molar to Palatal Plane Distance
L6–MP	Lower First Molar to Mandibular Plane Distance
PFH	Posterior Facial Height
OP	Occlusal Plane
MPA	Mandibular Plane Angle
RPE	Rapid Palatal Expander
RCT	Randomized Controlled Trial
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
OSF	Open Science Framework
MINORS	Methodological Index for Non-Randomized Studies
CI	Confidence Interval
MD	Mean Difference
SD	Standard Deviation
NR	Not Reported

Appendix A

Table A1. Search strategy and number of records retrieved in different databases: (a) main biomedical databases (PubMed, Scopus, Web of Science, Embase); (b) complementary regional/specialized sources (Cochrane, LILACS, Scielo, Epistemonikos); (c) additional databases (ScienceDirect, Google Scholar).

Database	Search Query *(Date Last Search: July 2025)*	Results
PubMed	"Open Bite" [Mesh] OR "anterior open bite" OR "openbite" OR "AOB" AND "Temporary Anchorage Devices" OR "skeletal anchorage" OR "TAD*" OR "miniscrew*" OR "mini-implant*" OR "miniplate*"AND "Cephalometry" [Mesh] OR cephalometric OR skeletal OR dentoalveolar OR "molar intrusion" OR "treatment stability" OR "follow-up"	129
Scopus	TITLE-ABS-KEY(("anterior open bite" OR "openbite" OR "AOB") AND ("Temporary Anchorage Devices" OR "skeletal anchorage" OR "TAD*" OR "miniscrew*" OR "mini-implant*" OR "miniplate*") AND (cephalometric OR skeletal OR dentoalveolar OR "molar intrusion" OR "treatment stability" OR "follow-up"))	162
Web of Science	TS = ("anterior open bite" OR "openbite" OR "AOB") AND TS = ("Temporary Anchorage Devices" OR "skeletal anchorage" OR "TAD*" OR "miniscrew*" OR "mini-implant*" OR "miniplate*") AND TS = (cephalometric OR skeletal OR dentoalveolar OR "molar intrusion" OR "treatment stability" OR "follow-up")	218
Embase	('anterior open bite'/exp OR 'openbite' OR 'AOB') AND ('temporary anchorage device'/exp OR 'skeletal anchorage' OR 'TAD*' OR 'miniscrew*' OR 'mini-implant*' OR 'miniplate*') AND ('cephalometry'/exp OR cephalometric OR skeletal OR dentoalveolar OR 'molar intrusion' OR 'treatment stability' OR 'follow-up')	543
Cochrane	("anterior open bite" OR "openbite" OR "AOB") AND ("Temporary Anchorage Devices" OR "skeletal anchorage" OR "TAD*" OR "miniscrew*" OR "mini-implant*" OR "miniplate*") AND (cephalometric OR skeletal OR dentoalveolar OR "molar intrusion" OR "treatment stability" OR "follow-up")	8
LILACS	("anterior open bite" OR "openbite" OR "AOB") AND ("Temporary Anchorage Devices" OR "skeletal anchorage" OR "TAD*" OR "miniscrew*" OR "mini-implant*" OR "miniplate*") AND (cephalometric OR skeletal OR dentoalveolar OR "molar intrusion" OR "treatment stability" OR "follow-up")	15
Scielo	("anterior open bite" OR "openbite" OR "AOB") AND ("Temporary Anchorage Devices" OR "skeletal anchorage" OR "TAD*" OR "miniscrew*" OR "mini-implant*" OR "miniplate*") AND (cephalometric OR skeletal OR dentoalveolar OR "molar intrusion" OR "treatment stability" OR "follow-up")	5
Epistemonikos	("anterior open bite" OR "openbite" OR "AOB") AND ("Temporary Anchorage Devices" OR "skeletal anchorage" OR "TAD*" OR "miniscrew*" OR "mini-implant*" OR "miniplate*") AND (cephalometric OR skeletal OR dentoalveolar OR "molar intrusion" OR "treatment stability" OR "follow-up")	80
ScienceDirect	("anterior open bite" OR "openbite" OR "AOB") AND ("Temporary Anchorage Devices" OR "skeletal anchorage" OR "TAD*" OR "miniscrew*" OR "mini-implant*" OR "miniplate*") AND (cephalometric OR skeletal OR dentoalveolar OR "molar intrusion" OR "treatment stability" OR "follow-up")	419
Google Scholar	allintitle: "anterior open bite" "skeletal anchorage" cephalometric stability	310

Table A2. The revised and validated version of MINORS Assesment Tool [19].

Methodological Items for Non-Randomized Studies	*Score **
· **A clearly stated aim**: the question addressed should be precise and relevant in the light of available literature · **Inclusion of consecutive patients**: all patients potentially fit for inclusion (satisfying the criteria for inclusion) have been included in the study during the study period (no exclusion or details about the reasons for exclusion). · **Prospective collection of data**: data were collected according to a protocol established before the beginning of the study	

Table A2. *Cont.*

Methodological Items for Non-Randomized Studies	*Score* *
· **Endpoints appropriate to the aim of the study**: unambiguous explanation of the criteria used to evaluate the main outcome, which should be in accordance with the question addressed by the study. Also, the endpoints should be assessed on an intention-to-treat basis.	
· **Unbiased assessment of the study endpoint**: blind evaluation of objective endpoints and double-blind evaluation of subjective endpoints. Otherwise, the reasons for not blinding should be stated.	
· **Follow-up period appropriate to the aim of the study**: the follow-up should be sufficiently long to allow the assessment of the main endpoint and possible adverse events.	
· **Loss to follow up less than 5%**: all patients should be included in the follow up. Otherwise, the proportion lost to follow up should not exceed the proportion experiencing the major endpoint.	
· **Prospective calculation of the study size**: information of the size of detectable difference in interest, with a calculation of 95% confidence interval, according to the expected incidence of the outcome event, and information about the level for statistical significance and estimates of power when comparing the outcomes.	
Additional criteria in the case of comparative study	
· **An adequate control group**: having a gold standard diagnostic test or therapeutic intervention recognized as the optimal intervention according to the available published data.	
· **Contemporary groups**: control and studied group should be managed during the same period (no historical comparison).	
· **Baseline equivalence of groups**: the groups should be similar regarding the criteria other than the studied endpoints. Absence of confounding factors that could bias the interpretation of the results.	
· **Adequate statistical analyses**: whether the statistics were in accordance with the type of study with calculation of confidence intervals or relative risk.	

* The items are scored 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate). The global ideal score being 16 for non-comparative studies and 24 for comparative studies. 0–10: low quality study; 11–15: Average quality study; 16–20: High-quality study; 21–24: Very High-quality study.

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