JHWCR JOURNAL OF HEALTH, WELLNESS AND COMMUNITY RESEARCH 3007-0570

https://doi.org/10.61919/18mhn732

Review Article

Three-Dimensional Temporomandibular Joint Adaptations and Skeletal Outcomes Following Herbst Appliance Therapy in Class II Malocclusion: A Systematic Review

Ana Luiza Monroy Francisconi Volles[1], Iram Nasir[2]

[1] Doctor of Dental Medicine, Rutgers School of Dental Medicine, New Jersey, USA
[2] Adjunct Faculty, New York University College of Dentistry; Chief Resident, Georgia School of Orthodontics, USA

***Corresponding author: Ana Luiza Monroy Francisconi Volles, anavolles@hotmail.com**

"Cite this Article" **Received**: 25 January 2026; **Accepted**: 29 April 2026; **Published**: 12 May 2026
Author Contributions: Concept: ALMFV; Design: IN; Data Collection: ALMFV; Analysis: IN; Drafting: ALMFV and IN.. **Ethical Approval**: Rutgers School of Dental Medicine, New Jersey, USA. **Informed Consent**: Written informed consent was obtained from all participants; **Conflict of Interest**: The authors declare no conflict of interest. **Funding**: No external funding; **Data Availability**: Available from the corresponding author on reasonable request; **Acknowledgments**: N/A.

ABSTRACT

Background: Class II malocclusion associated with mandibular retrognathism is frequently managed using functional orthopedic appliances, including the Herbst appliance. Continuous mandibular advancement may influence condylar remodeling, mandibular skeletal adaptation, dentoalveolar compensation, and temporomandibular joint response; however, the extent and stability of these effects remain uncertain. Objective: This systematic structured literature review aimed to evaluate recent clinical and imaging-based evidence on temporomandibular joint adaptations, condylar remodeling, glenoid fossa response, skeletal and dentoalveolar outcomes, and post-treatment stability following Herbst appliance therapy in patients with Class II malocclusion. Methods: PubMed, Scopus, and Web of Science were searched for studies published between 2015 and 2025. Eligible studies included primary longitudinal, comparative, clinical, and imaging-based investigations evaluating Herbst appliance therapy in relation to TMJ, skeletal, dentoalveolar, or stability outcomes. Reviews, meta-analyses, case reports, animal studies, non-English publications, and studies without relevant outcomes were excluded. Because of heterogeneity in study design, imaging protocols, comparators, and outcome measures, findings were synthesized qualitatively. Results: Six studies were included in the qualitative synthesis. The evidence was predominantly CBCT-based and primarily supported osseous condylar, mandibular, and condyle–glenoid fossa adaptations following Herbst therapy. Dentoalveolar and alveolar effects contributed to treatment response, and limited clinical follow-up evidence suggested relative stability of sagittal occlusal correction. Direct evidence on articular disc position, soft-tissue TMJ adaptation, TMD incidence, treatment timing superiority, and detailed relapse mechanisms was limited. Conclusion: Herbst appliance therapy appears to contribute to Class II correction through combined osseous TMJ adaptation, condylar remodeling, mandibular skeletal response, and dentoalveolar compensation. However, conclusions regarding disc status, soft-tissue TMJ safety, TMD risk, and long-term relapse mechanisms remain constrained by the predominance of CBCT-based observational evidence. Keywords: Herbst Appliance; Class II Malocclusion; Temporomandibular Joint; Cone-Beam Computed Tomography; Condylar Remodeling; Mandibular Advancement; Dentoalveolar Compensation; Treatment Stability.

INTRODUCTION

Class II malocclusion associated with mandibular retrognathism represents a clinically important sagittal discrepancy in orthodontic practice and is commonly characterized by deficient mandibular projection, increased overjet, altered molar relationship, and unfavorable facial profile in growing patients (1). Functional orthopedic appliances are used to improve mandibular position and sagittal jaw relationships during growth, particularly when mandibular retrusion is a major contributor to the malocclusion (2). Among these appliances, the Herbst appliance has received considerable clinical attention because it postures the mandible forward continuously and is less dependent on patient compliance than removable functional appliances. This continuous mandibular advancement creates a sustained orthopedic stimulus that may influence dentoalveolar correction, mandibular skeletal response, and adaptive remodeling within the temporomandibular joint complex (3).

The biological response to Herbst appliance therapy is generally understood as a combination of skeletal, dentoalveolar, and temporomandibular joint adaptations. Forward positioning of the mandible may alter the functional loading environment of the condyle–glenoid fossa complex, potentially influencing condylar morphology, condylar growth direction, glenoid fossa remodeling, and condyle–fossa spatial relationships. At the same time, correction of Class II malocclusion is not purely skeletal; dentoalveolar effects such as incisor inclination changes and molar relationship correction may contribute substantially to overjet reduction and occlusal improvement. Differentiating true skeletal adaptation from dental compensation is therefore essential when interpreting Herbst treatment outcomes, because the relative contribution of each mechanism may influence both treatment efficiency and post-treatment stability.

The temporomandibular joint is a central concern in functional mandibular advancement because it is a biologically active structure exposed to altered loading during treatment. Earlier concerns suggested that orthodontic or orthopedic interventions might contribute to temporomandibular disorders; however, contemporary evidence has increasingly emphasized that TMJ responses should be interpreted in relation to joint biology, baseline symptoms, imaging modality, and the distinction between adaptive remodeling and pathological change (4,5). This distinction is especially important in Herbst therapy because different imaging methods evaluate different tissue components. Cone-beam computed tomography provides detailed information on osseous structures such as the condyle, mandibular ramus, and glenoid fossa, whereas magnetic resonance imaging is required for direct assessment of soft-tissue structures, particularly the articular disc and retrodiscal tissues. Consequently, CBCT-based evidence can support conclusions about bony adaptation but cannot independently establish normal disc position or comprehensive soft-tissue TMJ health (6).

Recent three-dimensional imaging studies have improved understanding of the osseous effects of Herbst appliance therapy by allowing more precise assessment of condylar morphology, mandibular skeletal change, and condyle–glenoid fossa relationships than conventional two-dimensional cephalometry. Nevertheless, the available evidence remains heterogeneous in patient age, skeletal maturity, appliance protocol, treatment duration, comparator group, imaging method, follow-up period, and outcome definitions. These differences limit direct comparison across studies and make it difficult to determine whether observed changes represent transient positional adaptation, measurable skeletal remodeling, dentoalveolar compensation, or stable long-term correction. In addition, evidence regarding post-treatment stability remains limited, particularly in relation to treatment timing, retention quality, incisor inclination control, occlusal settling, and functional factors that may contribute to relapse.

Using a PICO framework, the population of interest in this review comprises growing patients with Class II malocclusion, particularly those with mandibular retrognathism; the intervention is Herbst appliance therapy; the comparators include pretreatment baseline records, untreated or matched Class II controls, or alternative Class II correction approaches where available; and the outcomes include osseous TMJ adaptation, condylar remodeling, glenoid fossa changes, skeletal and dentoalveolar effects, treatment timing, TMD-related findings, and post-treatment stability. An updated structured synthesis is justified because recent evidence increasingly uses CBCT-based three-dimensional assessment and provides more detailed information on bony TMJ and mandibular adaptations after Herbst therapy, while soft-tissue disc conclusions remain comparatively limited. Therefore, this review aims to systematically evaluate recent clinical and imaging-based evidence on temporomandibular joint adaptations, condylar growth and remodeling, glenoid fossa response, skeletal and dentoalveolar outcomes, treatment timing, and stability following Herbst appliance therapy in patients with Class II malocclusion.

MATERIALS AND METHODS

This study was designed as a systematic structured literature review with qualitative narrative synthesis. The review was conducted to evaluate recent primary clinical and imaging-based evidence on temporomandibular joint adaptations, condylar remodeling, glenoid fossa changes, skeletal and dentoalveolar effects, treatment timing, relapse, and post-treatment stability following Herbst appliance therapy in patients with Class II malocclusion. The review followed the principles of PRISMA 2020 reporting, but because the included studies were heterogeneous in design, imaging protocols, comparators, follow-up duration, and outcome definitions, a quantitative meta-analysis was not performed. The protocol was not prospectively registered, and this should be acknowledged as a methodological limitation.

The review question was structured according to a PICO framework. The population comprised patients with Class II malocclusion, particularly those with mandibular retrognathism or sagittal mandibular deficiency. The intervention was Herbst appliance therapy, either alone or as part of a staged orthodontic treatment protocol. Comparators included pretreatment baseline records, untreated or matched Class II controls, Class II elastics, or other available comparison groups reported in the included studies. The outcomes of interest included osseous temporomandibular joint adaptation, condylar growth or remodeling, glenoid fossa changes, mandibular skeletal effects, dentoalveolar changes, occlusal correction, treatment timing, relapse, post-treatment stability, and reported temporomandibular disorder-related findings.

A comprehensive electronic search was performed in PubMed, Scopus, and Web of Science to identify relevant studies published from 2015 to 2025. The search strategy combined terms related to the intervention, condition, anatomical structures, imaging modality, and outcomes. The core search terms included "Herbst appliance," "Herbst therapy," "Class II malocclusion," "mandibular retrognathism," "mandibular advancement," "temporomandibular joint," "TMJ," "condyle," "condylar remodeling," "condylar growth," "glenoid fossa," "cone-beam computed tomography," "CBCT," "magnetic resonance imaging," "MRI," "skeletal changes," "dentoalveolar changes," "stability," and "relapse." A representative search strategy was: ("Herbst appliance" OR "Herbst therapy" OR "fixed functional appliance") AND ("Class II malocclusion" OR "mandibular retrognathism" OR "mandibular advancement") AND ("temporomandibular joint" OR "TMJ" OR "condyle" OR "condylar remodeling" OR "glenoid fossa") AND ("CBCT" OR "cone-beam computed tomography" OR "MRI" OR "skeletal changes" OR "dentoalveolar changes" OR "stability" OR "relapse"). Retrieved records were exported to a reference management system, and duplicate records were removed before screening.

Studies were eligible for inclusion if they were primary longitudinal clinical studies, prospective or retrospective cohort studies, comparative clinical studies, clinical trials, or imaging-based investigations evaluating Herbst appliance therapy in patients with Class II malocclusion. Studies were required to report at least one relevant outcome related to temporomandibular joint adaptation, condylar position or morphology, condylar growth, glenoid fossa remodeling, skeletal correction, dentoalveolar change, occlusal stability, relapse, or post-treatment outcomes. Imaging-based studies using cone-beam computed tomography, computed tomography, magnetic resonance imaging, cephalometry, or other validated clinical assessment methods were considered eligible when they provided relevant extractable outcome data. Studies were excluded if they were narrative reviews, systematic reviews, meta-analyses, case reports, animal studies, non-English publications, or did not evaluate Herbst appliance therapy in relation to TMJ, skeletal, dentoalveolar, or stability outcomes. Secondary reviews and meta-analyses were excluded from the evidence synthesis because the purpose of this review was to summarize primary clinical and imaging-based evidence.

Study selection was performed in sequential stages. After duplicate removal, titles and abstracts were screened against the predefined eligibility criteria. Articles considered potentially relevant were retrieved in full text and assessed for final inclusion. Eligibility decisions were based on study design, population characteristics, intervention type, imaging or clinical assessment method, outcome relevance, comparator availability, and extractability of data. The screening process was summarized using a PRISMA-style flow diagram, including the number of records identified, duplicates removed, records screened, full-text articles assessed, full-text exclusions, and studies included in the qualitative synthesis. Reasons for exclusion at the full-text stage were categorized according to ineligible study design, unsuitable population or intervention, absence of relevant TMJ or skeletal outcomes, review/meta-analysis design, case-report design, animal study design, or language restriction.

Data extraction was performed using a standardized extraction form developed for the objectives of this review. Extracted variables included author name, year of publication, study design, sample size, patient age or growth stage where reported, Herbst appliance protocol, treatment duration, comparator or control group, imaging modality, follow-up period, TMJ findings, condylar positional or morphological changes, glenoid fossa adaptations, mandibular skeletal outcomes, dentoalveolar effects, occlusal correction, relapse patterns, and stability-related findings. For imaging-based studies, particular attention was given to whether the reported outcomes reflected osseous structures visible on CBCT or CT, or soft-tissue structures requiring MRI-based assessment. This distinction was important because CBCT can support interpretation of bony condylar and glenoid fossa adaptation but cannot directly establish articular disc status or comprehensive soft-tissue TMJ health.

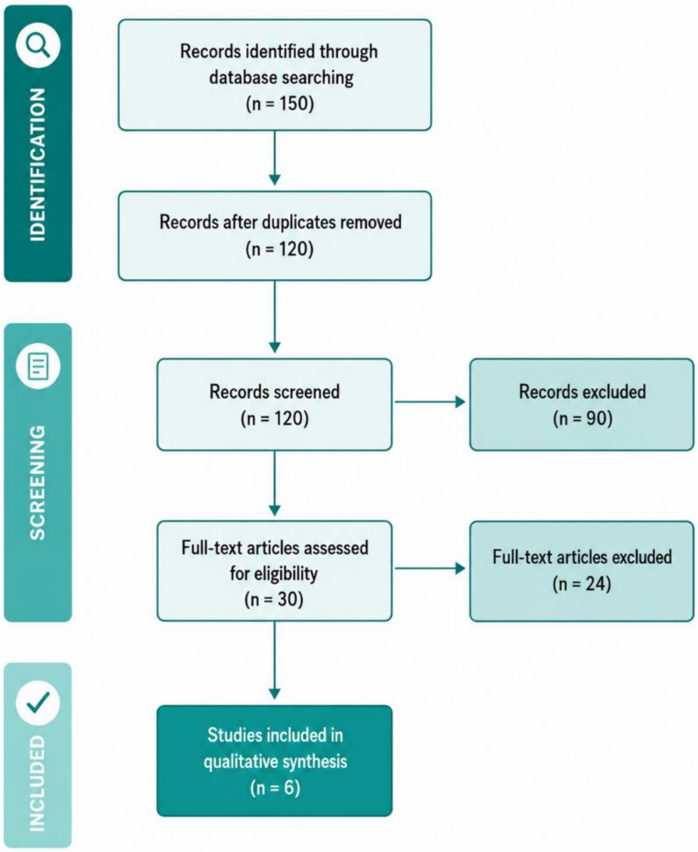

Figure 1 PRISMA Flowchart

Methodological quality and risk of bias were assessed at the study level using domains appropriate for non-randomized, observational, longitudinal, comparative, and imaging-based orthodontic studies. The assessed domains included clarity of eligibility criteria, adequacy of sample description, appropriateness of comparator or control group, baseline comparability, control of confounding factors, reliability and reproducibility of outcome measurements, consistency of imaging protocols, completeness of follow-up, transparency of statistical reporting, and relevance of outcomes to the review question. Each study was categorized as having low, moderate, or high overall risk of bias based on the combined judgment across these domains. Because the available evidence was expected to include non-randomized and imaging-based designs, particular emphasis was placed on sample size, selection bias, imaging standardization, measurement reliability, growth-stage assessment, and follow-up duration.

Due to clinical and methodological heterogeneity across the included studies, the findings were synthesized qualitatively rather than statistically pooled. The synthesis was organized around predefined outcome domains: temporomandibular joint adaptation, condylar growth and remodeling, glenoid fossa response, skeletal and dentoalveolar effects, treatment timing, relapse and stability, and evidence limitations. The direction and consistency of findings were compared across studies, with greater interpretive weight given to longitudinal and three-dimensional imaging-based evidence for osseous TMJ and mandibular skeletal outcomes. Conclusions were drawn cautiously by distinguishing directly supported osseous findings from weaker or indirect evidence related to articular disc status, soft-tissue TMJ adaptation, temporomandibular disorder risk, and long-term relapse mechanisms.

RESULTS

The database search identified 150 records from PubMed, Scopus, and Web of Science. After removal of 30 duplicate records, 120 records were screened by title and abstract. Ninety records were excluded during initial screening because they were not relevant to Herbst appliance therapy, Class II correction, temporomandibular joint adaptation, skeletal outcomes, dentoalveolar effects, or treatment stability. Thirty full-text articles were assessed for eligibility, of which 24 were excluded because they were reviews, case reports, animal studies, non-English publications, did not evaluate Herbst appliance therapy, or did not report relevant TMJ, skeletal, dentoalveolar, or stability outcomes. Six studies were included in the qualitative synthesis (7–12).

The included studies were published between 2016 and 2021 and comprised clinical, longitudinal, comparative, and imaging-based investigations. Most studies used cone-beam computed tomography (CBCT) or three-dimensional imaging methods to evaluate osseous changes involving the condyle, glenoid fossa, mandibular skeletal structures, or alveolar bone support (7–9,11,12). One study evaluated clinical occlusal stability after Herbst therapy (10). No randomized controlled trial was identified. Because the included studies differed in design, comparator groups, imaging protocols, outcome definitions, and follow-up duration, findings were synthesized qualitatively rather than statistically pooled.

Table 1. Characteristics of Included Studies Evaluating Herbst Appliance Therapy

Study No.	Study	Reference	Study Design	Main Assessment Method	Primary Outcome Domain	Contribution to Review
1	Nindra et al., 2021	(7)	CBCT-based longitudinal study	Three-dimensional CBCT assessment	Condyle–glenoid fossa complex	Osseous TMJ and condyle–fossa adaptation
2	Wei et al., 2020	(8)	CBCT-based comparative study	Three-dimensional condylar assessment	Condylar skeletal changes	Condylar remodeling after Herbst therapy compared with Class II elastics
3	Chen et al., 2016	(9)	CBCT-based imaging study	CBCT evaluation of TMJ bony structures	TMJ osseous changes	Bony condylar and glenoid fossa response during Herbst-based treatment
4	Bock et al., 2016	(10)	Clinical longitudinal follow-up study	Clinical and occlusal assessment	Occlusal stability and relapse	Post-treatment stability of sagittal occlusal correction
5	Schwartz et al., 2016	(11)	CBCT-based tomographic study	Tomographic alveolar assessment	Dentoalveolar and alveolar bone changes	Dental and alveolar compensation following Herbst therapy
6	Fan et al., 2020	(12)	CBCT morphometric study	Three-dimensional mandibular skeletal assessment	Mandibular skeletal and condylar adaptation	Mandibular skeletal effects and variability in treatment response

CBCT-based studies provided the main evidence for osseous TMJ and condylar adaptation after Herbst appliance therapy. Nindra et al. evaluated the condyle–glenoid fossa complex using three-dimensional CBCT and reported structural changes involving the condyle and glenoid fossa after treatment (7). Wei et al. compared three-dimensional condylar changes after Herbst appliance therapy with matched Class II elastics and contributed comparative evidence on condylar skeletal remodeling (8). Chen et al. evaluated bony TMJ structures during two-phase Herbst treatment and further supported osseous assessment of condylar and glenoid fossa response (9). Fan et al. assessed mandibular skeletal effects using three-dimensional imaging and reported mandibular and condylar responses after Herbst therapy, with variation in the magnitude of response among patients (12).

Table 2. Synthesis of Findings by Outcome Domain

Outcome Domain	Main Finding	Supporting Study/Studies	Evidence Strength	Interpretation
Osseous TMJ adaptation	Bony changes involving the condyle–glenoid fossa complex were reported after Herbst therapy	Nindra et al. (7); Chen et al. (9)	Moderate	Supports osseous adaptation of the TMJ complex
Condylar remodeling	Three-dimensional studies reported condylar skeletal changes after treatment	Nindra et al. (7); Wei et al. (8); Fan et al. (12)	Moderate	Condylar remodeling appears to contribute to Class II correction
Glenoid fossa response	CBCT evidence indicated condyle–fossa adaptation after Herbst therapy	Nindra et al. (7); Chen et al. (9)	Low to moderate	Fossa-related changes were reported, but their direction and persistence were not uniformly established
Mandibular skeletal effects	Three-dimensional mandibular assessment showed skeletal adaptation after Herbst therapy	Wei et al. (8); Fan et al. (12)	Moderate	Mandibular skeletal response was present, with variation among individuals
Dentoalveolar and alveolar effects	Tomographic assessment demonstrated dental and alveolar bone support changes	Schwartz et al. (11)	Moderate	Dentoalveolar and alveolar changes contributed to the treatment response
Occlusal stability	Clinical follow-up showed relative stability of sagittal occlusal correction	Bock et al. (10)	Low to moderate	Stability evidence was available but limited by study design and follow-up heterogeneity
TMD-related findings	Included studies did not provide robust direct assessment of TMD incidence or risk	Limited direct evidence	Low	TMD-related conclusions remain limited
Articular disc status	Direct disc-position evidence was limited because the included evidence was predominantly CBCT-based	No primary MRI-focused included study	Very low	Disc position and soft-tissue TMJ adaptation could not be reliably evaluated

The included studies supported the presence of osseous adaptive changes after Herbst appliance therapy, particularly within condylar and mandibular skeletal structures (7–9,12). These findings were mainly derived from CBCT-based or three-dimensional assessments and therefore apply primarily to bony structures. Direct conclusions regarding articular disc position, retrodiscal tissues, or comprehensive soft-tissue TMJ health were limited because MRI-based assessment was not routinely represented in the included evidence.

Table 3. Study-Level Risk of Bias and Evidence Limitations

Study	Reference	Main Methodological Limitation	Overall Risk of Bias	Impact on Interpretation
Nindra et al., 2021	(7)	CBCT-based design with limited soft-tissue assessment	Moderate	Supports bony adaptation but does not permit direct conclusions regarding disc position
Wei et al., 2020	(8)	Comparative design with potential treatment and group heterogeneity	Moderate	Provides useful comparative condylar evidence, but causal inference remains limited
Chen et al., 2016	(9)	CBCT-based assessment focused on bony TMJ structures	Moderate	Supports osseous TMJ evaluation but not soft-tissue assessment
Bock et al., 2016	(10)	Clinical follow-up design without randomization	Moderate	Supports occlusal stability findings but does not fully explain relapse mechanisms
Schwartz et al., 2016	(11)	Focused dentoalveolar and alveolar assessment	Moderate	Useful for dental and alveolar outcomes but limited for broader skeletal or TMJ conclusions
Fan et al., 2020	(12)	Imaging-based skeletal assessment with variable individual response	Moderate	Supports mandibular skeletal effects but highlights interindividual variability

Overall, the included evidence showed moderate methodological limitations. The main constraints were observational or non-randomized designs, small or variable sample sizes, differences in imaging protocols, variation in comparator groups, limited long-term follow-up, and limited MRI-based soft-tissue TMJ assessment. These limitations reduced the suitability of the evidence for quantitative pooling and supported the use of qualitative synthesis.

Table 4. Evidence Strength Across Review Outcomes

Outcome	Evidence Level	Main Evidence Base	Evidence-Based Interpretation
Condylar osseous remodeling	Moderate	CBCT and three-dimensional imaging studies (7,8,12)	Herbst therapy was associated with condylar remodeling and mandibular skeletal adaptation
Condyle–glenoid fossa adaptation	Low to moderate	CBCT studies (7,9)	Bony condyle–fossa adaptation was reported, but persistence of these changes remains uncertain
Mandibular skeletal change	Moderate	Three-dimensional mandibular assessment (8,12)	Mandibular skeletal response was observed, with variability among patients
Dentoalveolar and alveolar effects	Moderate	Tomographic assessment (11)	Dental and alveolar changes contributed to Class II correction
Occlusal stability	Low to moderate	Clinical follow-up study (10)	Sagittal occlusal correction appeared relatively stable in the available follow-up evidence
TMD risk	Low	Limited direct assessment in included studies	The included studies did not allow firm conclusions regarding TMD risk
Articular disc status	Very low	Lack of primary MRI-focused evidence	Disc position and soft-tissue adaptation remained insufficiently assessed
Treatment timing	Low	Limited direct comparative timing evidence	The included study set did not establish clear superiority of early, pubertal, or post-pubertal treatment timing

In summary, the strongest findings from the included studies related to CBCT-detectable osseous changes involving the condyle, mandible, and condyle–glenoid fossa complex (7–9,12). Evidence for dentoalveolar and alveolar changes was available but more focused and should be interpreted within the measured outcomes of the tomographic study (11). Evidence for occlusal stability was clinically relevant but was mainly supported by one follow-up study (10). Conclusions regarding articular disc position, TMD incidence, treatment timing superiority, and detailed relapse mechanisms remained limited because these outcomes were not directly or consistently assessed across the included primary studies.

DISCUSSION

This systematic structured literature review synthesized recent clinical and imaging-based evidence on temporomandibular joint adaptations, condylar remodeling, glenoid fossa response, mandibular skeletal effects, dentoalveolar changes, and post-treatment stability following Herbst appliance therapy in patients with Class II malocclusion. Across the six included studies, the available evidence primarily supported osseous adaptation rather than comprehensive soft-tissue TMJ conclusions. Most included studies used CBCT or three-dimensional imaging to evaluate bony structures, while direct MRI-based assessment of the articular disc was not routinely represented. Therefore, the strongest conclusions from this review relate to condylar, mandibular, and condyle–glenoid fossa osseous changes, whereas conclusions regarding articular disc position, soft-tissue TMJ response, and TMD risk remain limited (7–12).

The included CBCT-based studies suggest that Herbst appliance therapy is associated with adaptive changes in the condyle–glenoid fossa complex. Nindra et al. reported three-dimensional changes involving the condyle and glenoid fossa after Herbst therapy, while Chen et al. provided additional CBCT-based evidence on bony TMJ structures during Herbst-based treatment (7,9). These findings support the biological plausibility that forward mandibular positioning may alter the functional loading environment of the TMJ and induce osseous adaptation. However, the evidence should be interpreted cautiously because CBCT identifies structural bony changes but cannot directly determine articular disc position, retrodiscal tissue status, joint effusion, or other soft-tissue findings. Consequently, the absence of reported osseous degeneration should not be interpreted as definitive evidence of complete TMJ soft-tissue safety.

Condylar remodeling and mandibular skeletal response were central findings of the review. Wei et al. provided comparative three-dimensional evidence of condylar changes after Herbst therapy in relation to matched Class II elastics, while Fan et al. reported mandibular skeletal and condylar responses using three-dimensional morphometric assessment (8,12). Together with the findings of Nindra et al., these studies support the interpretation that Herbst therapy can contribute to Class II correction through condylar and mandibular skeletal adaptation (7,8,12). Nevertheless, the magnitude of skeletal response appears variable across patients, and the available evidence does not support a uniform or predictable mandibular growth response in all cases. Individual growth potential, skeletal maturity, baseline mandibular morphology, appliance protocol, and treatment duration are likely to influence the extent of skeletal adaptation.

Glenoid fossa response was also identified as a relevant component of TMJ adaptation, but the evidence was less consistent than for condylar and mandibular skeletal changes. CBCT-based studies reported changes involving the condyle–glenoid fossa complex, indicating that the fossa may participate in adaptive remodeling during Herbst treatment (7,9). However, the direction, magnitude, and persistence of glenoid fossa changes were not uniformly established across the included evidence. Therefore, glenoid fossa adaptation should be described as a possible osseous response rather than as a consistently proven or permanent mechanism of correction. Future studies using standardized three-dimensional measurement protocols and longer follow-up are needed to clarify whether fossa changes persist after active treatment or mainly represent temporary functional adaptation.

The dentoalveolar contribution to Herbst correction was supported mainly by tomographic evidence from Schwartz et al., who evaluated alveolar bone support changes associated with Herbst appliance therapy (11). These findings confirm that Class II correction after Herbst treatment should not be interpreted as purely skeletal. Dental and alveolar changes may contribute meaningfully to overjet reduction, molar relationship correction, and occlusal improvement. However, the current evidence base does not justify broad generalized claims regarding upper incisor retroclination, lower incisor proclination, molar mesial drift, or specific relapse pathways unless these outcomes are directly measured and consistently reported. The clinical effect of Herbst therapy is therefore best understood as a combined orthopedic–orthodontic response involving skeletal adaptation and dentoalveolar compensation.

Evidence regarding post-treatment stability was available but limited. Bock et al. provided clinical follow-up evidence suggesting relative stability of sagittal occlusal correction after Herbst therapy (10). However, stability and relapse were not assessed uniformly across the included studies, and detailed relapse mechanisms could not be firmly established. Claims that relapse is primarily caused by tongue interposition, inadequate retention, molar mesial drift, or specific incisor changes should therefore be interpreted with caution unless supported by direct study-level evidence. Similarly, although treatment timing and skeletal maturity are clinically important in functional appliance therapy, the included study set did not provide sufficient direct comparative evidence to establish clear superiority of early, pubertal, or post-pubertal Herbst treatment timing.

The interpretation of TMD-related findings requires particular caution. The included studies did not provide robust direct evidence on TMD incidence, and most relied on CBCT-based assessment of osseous structures rather than MRI-based evaluation of soft-tissue TMJ components. Contextual evidence from broader orthodontic and Herbst-related TMD reviews suggests that orthodontic treatment is not consistently associated with increased TMD prevalence, but these sources were not part of the primary-study synthesis of the present review (13,14). Therefore, the findings of this review should be framed narrowly: the included primary studies did not report clear osseous degenerative TMJ changes, but they do not allow firm conclusions regarding TMD risk, disc displacement, or long-term soft-tissue TMJ safety.

This review has several methodological limitations. The included evidence consisted mainly of observational, comparative, longitudinal, and imaging-based studies, with no randomized controlled trials identified. Sample sizes, patient age ranges, growth stages, appliance protocols, comparator groups, imaging methods, measurement protocols, and follow-up durations varied across studies. This heterogeneity prevented quantitative pooling and required qualitative synthesis. In addition, the dominance of CBCT-based evidence strengthened interpretation of osseous adaptation but limited conclusions regarding articular disc position and other soft-tissue TMJ outcomes. The absence of a registered protocol, the restriction to studies published between 2015 and 2025, and the exclusion of non-

English studies may also have influenced study selection and should be considered when interpreting the findings.

Despite these limitations, the review provides a focused synthesis of recent primary evidence on Herbst appliance therapy and highlights an important distinction between bony TMJ adaptation and soft-tissue TMJ safety. Clinically, Herbst therapy appears to contribute to Class II correction through combined condylar remodeling, mandibular skeletal adaptation, and dentoalveolar change. However, treatment planning should account for patient-specific growth potential, baseline skeletal pattern, incisor inclination, occlusal finishing, retention requirements, and TMJ history. Future research should prioritize prospective controlled studies with standardized growth-stage classification, uniform Herbst appliance protocols, calibrated CBCT-based osseous measurements, appropriate MRI assessment where disc status is relevant, and longer follow-up to clarify stability and relapse mechanisms.

CONCLUSION

Within the limitations of predominantly observational and CBCT-based evidence, Herbst appliance therapy appears to contribute to Class II malocclusion correction through combined condylar remodeling, mandibular skeletal adaptation, condyle–glenoid fossa osseous response, and dentoalveolar compensation. The strongest evidence supports bony condylar and mandibular changes, whereas conclusions regarding articular disc position, soft-tissue TMJ adaptation, TMD risk, treatment timing superiority, and detailed relapse mechanisms remain limited. Future prospective studies with standardized imaging protocols, growth-stage stratification, MRI-based soft-tissue assessment where indicated, and longer follow-up are needed to clarify the relative contribution and stability of skeletal, dentoalveolar, and TMJ-related treatment effects.

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