

# Alveolar Bone and Gingival Changes in Mandibular Anterior Region Following Herbst Appliance Therapy: A Systematic Review and Meta-analysis

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## ABSTRACT

**Objective:** To assess the alveolar bone changes and gingival recession following Herbst appliance therapy.

**Materials and methods:** Electronic databases such as PubMed, Ovid, Cochrane Library, Lilacs, Scopus, Web of Science, and Embase were searched until August 2022. Hand-searching of major orthodontic journals was performed to identify all peer-reviewed articles potentially relevant to the review. The quality of the selected studies was ranked using the revised Cochrane risk of bias tool for nonrandomized trials—Risk of Bias In Nonrandomized Studies (ROBINS) 1.

**Results:** Five relevant articles (all nonrandomized studies) were considered for qualitative analysis. The risk of bias was low for four studies and moderate for one. The reduction in the vertical alveolar bone height was  $0.13 \pm 0.07$  mm, with the Herbst appliance. The mean difference in the loss of buccal cortical thickness between the Herbst appliance and untreated control group was  $0.22$  mm [95% confidence interval (CI) of  $-0.62-0.18$ ]. Subsequent to Herbst appliance therapy, in the mandibular anterior region  $0.1 \pm 0.5$  mm of gingival recession was observed.

**Conclusion:** Herbst appliance treatment produces a negligible reduction in the buccal cortical thickness, vertical alveolar bone height, and gingival recession.

**Clinical significance:** Though the changes produced by the Herbst appliance were minimal, they are clinically important considering the young age of the patients warranting periodic periodontal assessment.

**Keywords:** Bone loss, Functional appliances, Gingival recession, Herbst appliance, Lower incisor.

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## INTRODUCTION

The inclination and position of lower incisors are important factors to be considered when planning orthodontic tooth movement. When an orthodontic force is applied to a tooth, it will move in the direction of the force being applied.<sup>1</sup> In recent years, there have been several investigations on the topic of the proclination of the mandibular anterior and the effects on the adjoining gingiva and alveolar bone.<sup>2,3</sup> Excess proclination of lower incisors after orthodontic therapy can lead to the development of gingival recession.<sup>2</sup> Conversely, no correlation has been found between the degree of proclination of mandibular central incisors and the occurrence of gingival recession.<sup>3</sup>

Herbst appliance which is one of the most commonly used functional appliances to treat skeletal class II malocclusion with retrognathic mandible induces favorable forward mandibular displacement.<sup>4</sup> However, as it applies a protrusive force on the lower incisors, a significant after-effect is proclination of lower incisors,<sup>5,6</sup> which in turn could affect the gingiva<sup>2</sup> and labial alveolar bone.<sup>7</sup> Following functional appliance therapy, the posttreatment changes analyzed using the Peer Assessment Rating (PAR) index showed that most of the overjet correction achieved was through lower incisor proclination.<sup>8</sup> As functional appliances are the treatment of choice in growing patients with retrognathic mandible,<sup>9</sup> especially with the resultant iatrogenic lower incisor proclination, the assessment of the periodontal health following functional therapy becomes of paramount importance.

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Therefore, the aim was to systematically review and assess the alveolar bone changes and gingival recession following Herbst appliance therapy.

## MATERIALS AND METHODS

The current systematic review was prepared in compliance with the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) 2020 statement and the Cochrane Handbook for Systematic Reviews of Interventions.<sup>10</sup>

The research question was “Does Herbst appliance therapy of patients with class II malocclusion lead to buccal bone loss and gingival recession?”

### Protocol and Registration

With The International Prospective Register of Systematic Reviews (PROSPERO) registry, this systematic review protocol was registered (No. CDR42021230587).

### Eligibility Criteria

#### Information Sources, Search Strategy, and Study Identification

A computerized systematic search was performed until August 2022 on Web of Science, Scopus, Lilacs, Ovid, Cochrane Library, PubMed, and Embase databases. To make certain that no pertinent studies were missed, hand-searching of four major orthodontic journals (American Journal of Orthodontics and Dentofacial Orthopedics, European Journal of Orthodontics, Progress in Orthodontics and the Angle Orthodontist) between 2011 and August 2022 and references of eligible studies were done (Table 1).

The search strategy included the use of Medical Subject Headings (MeSH), keywords, and Boolean operators “AND” and “OR.” An attempt was made to recognize all pertinent studies regardless of the language. The keywords and the search database outline are presented in Table 2.

### Selection of Studies

The search with the chosen keywords was conducted across the databases independently by two reviewers. The studies were streamlined based on the research question and eligibility criteria. Where adequate information was not elicited from the title and abstract, full-text articles were screened independently by two

researchers. Any differences were sorted through discussion and if required, the third researcher was involved. These studies were then assessed for their appropriateness for quantitative and qualitative reviews.

### Data Extraction and Management

Two researchers worked separately to extract the data. Conflicts were settled through conversation or the third researcher's involvement. Using a specially designed data collection form, the following data was gathered—(1) author, title, and year; (2) design; (3) number, age, and gender of participants in the control or intervention groups; (4) type of appliance, number of advancements; (5) method of analyzing recession; (6) observation period (follow-up of patients); and (7) method of outcome assessment.

### Quality Assessment of Included Studies

Using the updated Cochrane risk of bias tool<sup>9</sup> Risk of Bias In Nonrandomized Studies (ROBINS) 1 for nonrandomized trials,<sup>11</sup> the included studies' quality was evaluated.

The risk of bias (RoB) for nonrandomized trials was determined for the following domains—(1) bias due to confounding; (2) bias in the selection of participants into the study; (3) bias in the classification of interventions; (4) bias due to deviations from intended interventions; (5) bias due to missing data; (6) bias in the measurement of outcomes; and (7) bias in the selection of the reported result.

Each of the included studies' RoB was evaluated independently by two researchers. Conflicts were settled by consensus-building and discussion, or, if needed, the third researcher's judgment was considered.

**Table 1:** Eligibility criteria

	<i>Inclusion criteria</i>	<i>Exclusion criteria</i>
Population	Skeletal class II patients, growing patients treated with Herbst appliances	Patients treated with appliances other than Herbst appliance, craniofacial anomalies, syndromic patients, and adult patients
Intervention	Herbst appliance, availability of data prefunctional and immediately postfunctional appliance treatment	Other functional and nongrowth modification treatment modalities
Comparison	Patients treated with other functional appliances, self-control or no interventions	
Outcome	Gingival recession and bone loss measured on the mandibular anteriors with dental casts, photographs, or CBCT	
Study design	Randomized controlled trials, controlled clinical trials, cohort studies of prospective and retrospective design, cross-sectional studies, gray literature, and unpublished data	Systematic reviews, meta-analysis, case series, case reports, expert opinion, editorials review articles, and animal studies

**Table 2:** Summary of search database

Search Strategy	Database	Number of Studies
“Herbst”(MeSH) OR “Orthodontic appliances” [All Fields] OR “functional”[All Fields] AND (“Recession, incisor”[MeSH] OR “bone loss”[All Fields] OR “orthop*”[All Fields]) AND (“Class”[All Fields] AND “II”[All Fields] AND “Malocclusion”[All Fields]) OR (“Angle”[All Fields] AND “Class”[All Fields] AND “II” [All Fields])	PubMed	915
(Herbst appliance) AND ((recession) OR (bone loss))	Cochrane	3
(Herbst appliance) AND((recession) OR (bone loss))	Lilac	7
(Herbst appliance) AND ((recession) OR (bone loss))	Ovid	1,276
“Herbst AND recession” “Herbst AND bone loss” “Herbst AND oral health” “Herbst AND periodontal disease” “Herbst AND gingival health” “Functional appliances AND recession”	Embase	165
(Herbst appliance) AND ((recession) OR (bone loss))	Scopus	830
“Herbst AND recession” “Herbst AND bone loss” “Herbst AND oral health” “Herbst AND periodontal disease” “Herbst AND gingival health” “Functional appliances AND recession”	WOS	118

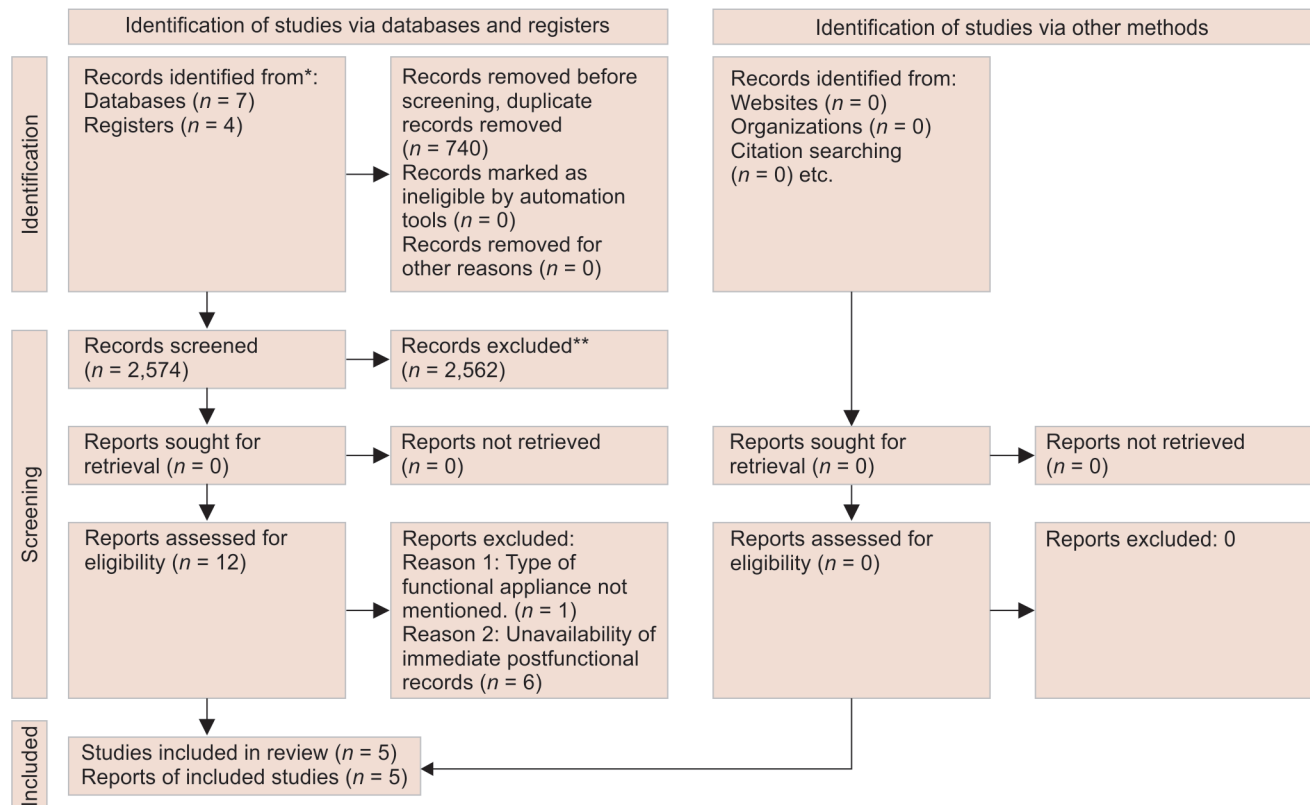


Fig. 1: PRISMA flowchart 2020

## Data Synthesis

The data from the articles that satisfied the validity requirements were retrieved and put together (Table 3). The data was analyzed using Review Manager (RevMan) 5.3.<sup>12</sup> The mean difference and 95% confidence interval were used to present the continuous data. The meta-analysis employed a random-effects model pooled data approach using inverse variance. Using  $I^2$  statistics, the heterogeneity of the included studies was evaluated (range—0–100%). A <25% of the  $I^2$  index denotes low heterogeneity, 25–75% denotes average heterogeneity, and >75% denotes significant heterogeneity.<sup>13</sup>

## RESULTS

The results are summarized as a PRISMA flowchart (Fig. 1).<sup>14</sup> The electronic search of seven databases yielded a total of 3,314 articles. After duplicate removal, 2,574 records were screened, out of which 2,562 articles were eliminated based on the title and abstracts. The resultant 12 documents which were selected for full-text evaluation were critically evaluated. Seven studies were excluded after full-text evaluation and the reasons for exclusion were noted. Finally, five studies<sup>15–19</sup> were included in the qualitative assessment. For quantitative assessment, two articles were included and forest plots were generated using RevMan software. Three articles were excluded due to methodological heterogeneity.

All studies included in the systematic review were nonrandomized in design. The studies had a sample size ranging from 14 to 98, with the mean age ranging from 8.2 to 15.7 years during the pretreatment stage. The protocols of the

included studies in the current systematic review are listed in Table 3.

## Study Design and Treatment Interventions

The selection of participants was prospective in one study<sup>15</sup> and retrospective in four studies.<sup>16–19</sup> The type of Herbst appliance used was banded<sup>15,18</sup> and the cantilever type of Herbst appliance<sup>16,17</sup> Ruf et al. did not mention the type of Herbst appliance used.<sup>19</sup>

The amount of bone loss that developed after functional appliance therapy was analyzed using cone beam computed tomography (CBCT) in three articles.<sup>15–17</sup>

Gerszewski et al.<sup>16</sup> and Bié et al.<sup>17</sup> measured this as the loss of buccal cortical bone thickness, whereas Schwartz et al.<sup>15</sup> evaluated bone loss as the decrease in the vertical alveolar bone height.<sup>15,17</sup>

Pancherz and Bjerklin<sup>18</sup> and Ruf et al.<sup>19</sup> evaluated gingival recession. The number of teeth that had developed gingival recession after functional appliance therapy was assessed using photographs in both studies.<sup>18,19</sup> The distance from the deepest point of the vestibulogingival margin to the incisal edge was additionally evaluated using dental casts by Ruf et al.<sup>19</sup>

## QUALITATIVE ANALYSIS

### Risk of Bias

The overall risk of bias for the included studies was assessed to be low in four of the included studies<sup>15–18</sup> and moderate in one study.<sup>19</sup> The traffic signal plot and a weighted summary plot<sup>20</sup> representing the summary of the risk of bias assessment of the included studies have been described in Figures 2 and 3.

Table 3: Protocols of the studies included in the present systematic review

S. Author no. (year)	Title	Study design	Cervical vertebral maturation index	Time period	Treatment duration	Sample	Mean age	Type of appliance	Number of advancements	Method of analyzing recession/bone loss	Results
1. Schwartz et al. 2016	Changes in alveolar bone support induced by the Herbst appliance—a tomographic evaluation <sup>15</sup>	Prospective study	Not mentioned	T0—before Herbst treatment T1—after immediate Herbst treatment	8 months of treatment (mean 8.50 ± 0.70 months)	23 patients (11 males and 12 females) 92 lower incisors	15.76 ± 1.75 years	Banded Herbst appliance	Single mandibular advancement until incisors were in an edge-to-edge relationship	CBCT	Alveolar bone loss present but without clinical significance
2. Geiszewski et al. 2018	Dentoalveolar evaluation of lower incisors by CBCT after treatment with Herbst appliance <sup>16</sup>	Retrospective study	Not mentioned	Treatment group—12 months of treatment T1—before treatment, T2—end of Herbst appliance treatment Control group—18 months follow-up T1—the start of the observation period T2—at the end of the observation period	12 months of treatment	Treatment group—22 (14 males and 8 females) Control group—13 (10 males and 3 females) 140 lower incisors	Control group—8.9 years Treatment group—8.2 years	Treatment group—Herbst appliance Control group—no treatment	Not mentioned	CBCT	No alveolar bone loss
3. Bié et al. 2013	Avaliação tomográfica da região dos incisivos inferiores após o tratamento com o aparelho de Herbst Tomographic evaluation of lower incisors after treatment using Herbst appliance <sup>17</sup>	Pilot study	Not mentioned	T0—before treatment T1—control group after 18 months T1— T1—	6 months	Control group—10 patients (3 females and 7 males) Treatment group—6 patients (2 females and 4 males) Total of 16 patients	G1—initial and final mean ages of 8.9–10.4 years G2—initial and final mean ages of 10.8–11.4 years	Herbst appliance with cantilever	Single step advancement with median anterior advancement of 7.2 mm	CBCT	
4. Panchez and Bjerklín 2014	Mandibular incisor inclination, tooth irregularity, and gingival recessions after Herbst therapy—a 32-year follow-up study <sup>18</sup>	Retrospective study	Not mentioned	T1—before Herbst treatment T2—12 months after Herbst appliance removal T3—6 years after treatment T4—32 years after treatment	Not mentioned	14 patients (12 males and 2 females) 56 lower incisors	At T1—11–13.5 years At T2—12.5–25 years At T3—18.5–22 years At T4—42–48 years	Herbst appliance (no further fixed appliance treatment after the Herbst phase)	Not mentioned	Photographs	Minor gingival recession evident but not related to postfunctional inclination changes
5. Ruf et al. 1998	Does orthodontic proclination of lower incisors in children and adolescents cause gingival recession? <sup>19</sup>	Retrospective study	Not mentioned	T1—before Herbst treatment T2—after immediate Herbst treatment	6 months	98 patients (67 males and 31 females) 392 mandibular incisors were evaluated for gingival recession	Mean age—12.8 ± 1.4 years	Herbst appliance	Not mentioned	Dental casts and photographs	No recession evident

**Results of Individual Studies: Buccal Bone Evaluation**

*Studies Measuring Vertical Alveolar Bone Height*

A reduction of  $0.13 \pm 0.07$  mm ( $p$ -value—0.090) in the vertical alveolar bone height was observed by Schwartz et al.<sup>15</sup> (low RoB) with Herbst appliance.

*Studies Measuring Buccal Bone Thickness*

Buccal bone loss was observed following Herbst appliance therapy with Gerszewski et al.<sup>16</sup> (low RoB) and Mércia et al.<sup>17</sup> (low RoB). As both the studies followed a similar study design and appliance the data was pooled and a meta-analysis was performed.

**Evaluation of Gingival Recession**

Ruf et al.<sup>19</sup> (moderate RoB) on evaluation of dental casts found mean gingival recession (T2-T1) of  $-0.1 \pm 0.6$  in 32,  $0.1 \pm 0.5$  in 31,  $0.1 \pm 0.5$  in 41, and  $-0.1 \pm 0.5$  in 42. New recessions developed in eight teeth (2%) on evaluation of intraoral photographs. Pancherz and Bjerklin<sup>18</sup> (low RoB) found a single recession in the mandibular anterior region in one patient following Herbst appliance therapy. No interrelationship was observed between the amount of incisor proclination and the development of gingival recession.

**QUANTITATIVE ANALYSIS**

**Meta-analysis**

The change in the buccal cortical thickness was evaluated between the treatment group (28 patients treated using cantilever type Herbst appliance) and the untreated control group (23 participants).

The outcomes of interest tested were overall buccal bone loss in the mandibular anterior region and subgroup analyzes in relation to the regions—32–31, 31–41, and 41–42 (Figs 4 to 7).

Between Herbst appliance therapy and the untreated control group, the mean difference in bone loss in the mandibular anterior region was  $-0.22$  (95% CI of  $-0.62$ – $0.18$ ). The  $I^2$  value was found to be 64% suggestive of considerable heterogeneity (Fig. 4).

Bone loss in relation to the interdental region between 32 and 31—Herbst appliance therapy vs untreated control group—the mean difference in bone loss was  $-0.12$  (95% CI of  $-0.32$ – $0.08$ ). The  $I^2$  value was found to be 0% suggestive of low heterogeneity (Fig. 5).

Bone loss in relation to the interdental region between 31 and 41—Herbst appliance therapy vs untreated control group—the mean difference in bone loss was  $-0.06$  (95% CI of  $-0.26$ – $0.14$ ). The  $I^2$  value was found to be 0% suggestive of low heterogeneity (Fig. 6).

Bone loss in relation to the interdental region between 41 and 42—Herbst appliance therapy vs untreated control group—the mean difference in bone loss was 0 (95% CI of  $-0.18$ – $0.19$ ). The  $I^2$  value was found to be 5% suggestive of low heterogeneity (Fig. 7).

**DISCUSSION**

One among the dentoalveolar sequelae brought about by Herbst appliance therapy is lower incisor proclination,<sup>5</sup> which is believed to lead to gingival recession and bone loss.<sup>6</sup> The position of mandibular incisors is considered optimal and stable when present in the medullary portion of the alveolar bone, in harmony with the neighboring muscular structures.<sup>21</sup> The symphysis provides the limit for the labiolingual movement of incisors. However, when thin alveolar bone plates are present (buccal and/or lingual plates), they are susceptible to periodontal malady.<sup>22</sup> Therefore, the excessive inclination of incisors must be avoided to prevent loss of alveolar bone and the subsequent damage to the periodontal support of the tooth,<sup>23–25</sup> thus highlighting the importance of the current study for there is no systematic review in the literature evaluating

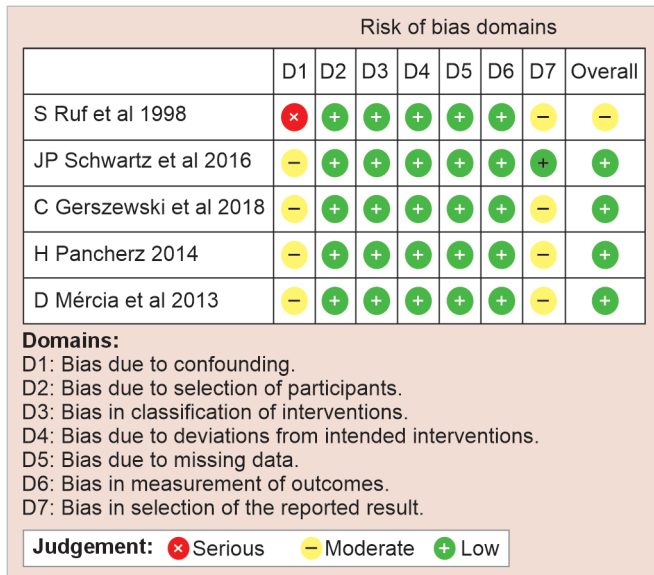


Fig. 2: Traffic signal plot

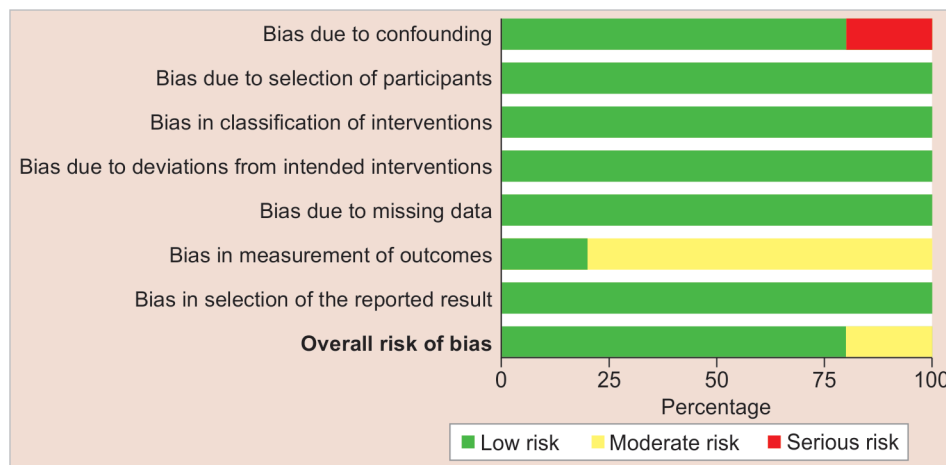


Fig. 3: Weighted summary plot

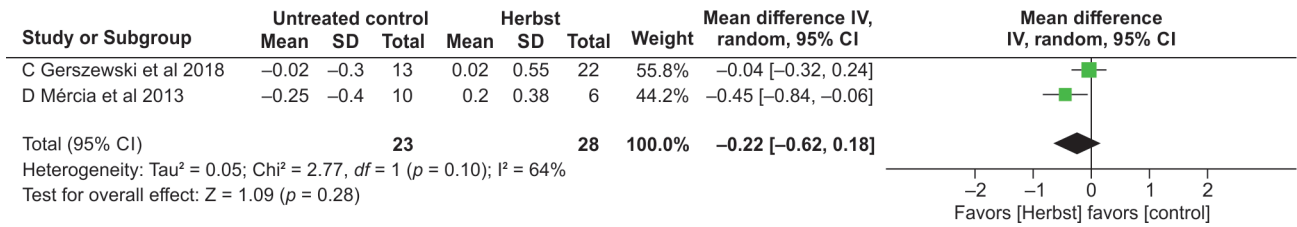


Fig. 4: Comparison of buccal bone loss between treatment and control group in relation to lower incisors

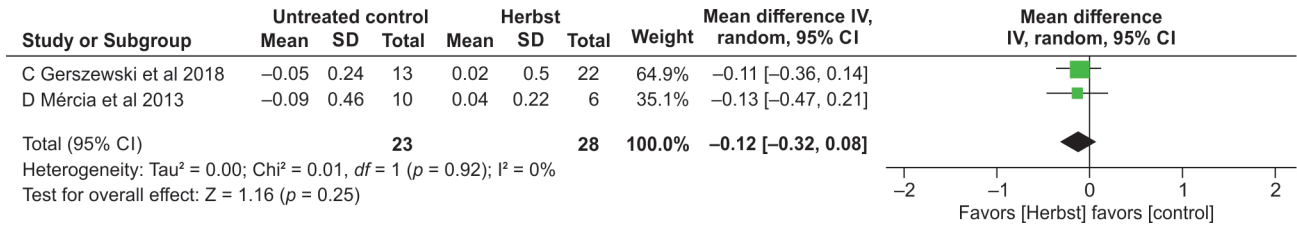


Fig. 5: Comparison of buccal bone loss between treatment and control group in relation to 32–31

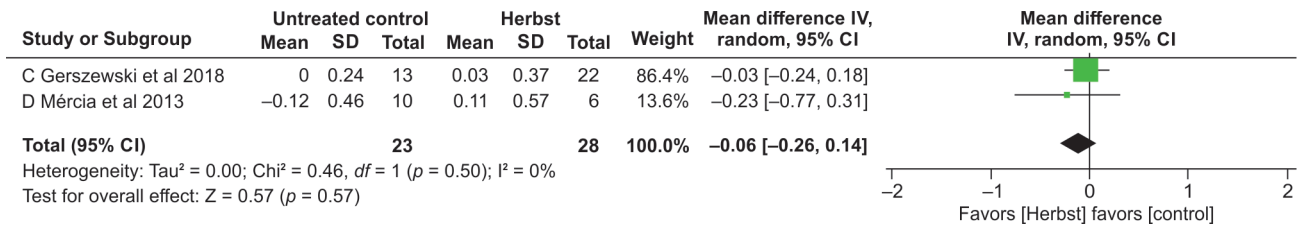


Fig. 6: Comparison of buccal bone loss between treatment and control group in relation to 31–41

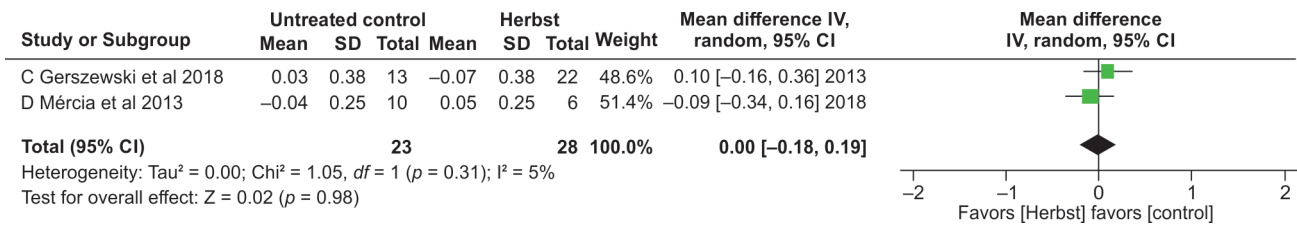


Fig. 7: Comparison of buccal bone loss between treatment and control group in relation to 41–42

the periodontal effect of forward movement/proclination of mandibular incisors induced by the Herbst appliances.

This review includes five studies with nonrandomized designs. The current systematic review analyzed the risk of bias in all the selected articles using the ROBINS 1 tool, which showed four studies to have a low risk of bias<sup>15–18</sup> and one study with a moderate risk of bias.<sup>19</sup>

Schwartz et al.<sup>15</sup> (low RoB) on evaluation of changes in the vertical alveolar bone height, identified minimal reduction in bone height following treatment with Herbst. Gerszewski et al.<sup>16</sup> (low ROB) and Bié et al.<sup>17</sup> (low ROB) evaluated the loss of buccal cortical thickness using CBCT. The reduction in the buccal cortical thickness following Herbst appliance therapy was not statistically and clinically significant.<sup>16,17</sup> As the methodology of the two studies was homogenous in nature making the availability of quantitative data with increased sample size possible, a meta-analysis was performed to quantitatively assess the changes in the buccal cortical thickness with Herbst appliance.<sup>16,17</sup> The pooled-in results showed a reduction in the buccal cortical thickness in the lower anterior with the Herbst appliance group when compared to the untreated control group (Fig. 4). However,

a considerable heterogeneity was observed (Fig. 4). The subgroup meta-analyses revealed minimal reduction in the buccal cortical thickness in relation to the individual regions in the Herbst group when compared to the control group. The assessment of gingival recession by Pancherz and Bjerklín<sup>18</sup> (low ROB) and Ruf et al.<sup>19</sup> (moderate ROB) showed minimal change that was not significant.

Though the lower incisor proclination was significant, the associated changes in the periodontium, especially the loss of alveolar bone support and height were present but minimal. However, as these patients are in their adolescence and any periodontal loss at this age would have critical detrimental consequences to the future periodontal health, it would be prudent for the clinician to constantly assess the periodontal status during the functional appliance therapy.

**Limitations of the Review**

Factors that could have influenced the treatment outcome include the type of appliance used, the number and quantum of advancement, duration of treatment, pretreatment mandibular incisor proclination, oral hygiene, and the biotype.

## CONCLUSION

Alveolar bone and gingival changes were evaluated following Herbst appliance therapy. ROBINS 1 tool indicated that the risk of bias was low in four studies and moderate in one study. Herbst appliance treatment produced a reduction in the buccal cortical thickness, vertical alveolar bone height, and gingival recession. Though these changes were minimal, they are clinically important considering the young age of the patients warranting periodic periodontal assessment.

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