

# Herbst Appliance for Adolescent Angle Class II Division 1 Malocclusion Long-Term Stability: A Systematic Reviews and Meta-Analysis

Fei Lei<sup>1</sup>, Jing Guan<sup>2</sup>, Mingrui Zhang<sup>3</sup> & Qing Dong<sup>1</sup>

<sup>1</sup> North China University of Science and Technology, Tangshan, China

<sup>2</sup> HeBei General Hospital, Shijiazhuang, China

<sup>3</sup> North China University of Science and Technology, Tangshan, China

Correspondence: Qing Dong, North China University of Science and Technology, Tangshan, China.

doi:10.56397/CRMS.2024.03.07

## Abstract

**Objective:** To conduct a systematic and comprehensive literature search to systematically evaluate and meta-analysis the long-term stability of treatment results obtained after treatment with Herbst functional appliance, and to provide scientific evidence. **Methods:** CNKI, WANFANG, CBM, VIP, PubMed, Embase, The Cochrane Library and other literature databases were searched as comprehensively as possible. The two groups of researchers formulated inclusion criteria and exclusion criteria according to PICOS principles, screened literature, extracted data, and evaluated the quality of the selected literature according to the MINORS evaluation table. Meta-analysis was performed using data extracted from Review Manager 5.3 software. **Results:** A total of 12 literatures were included, with a total sample size of 490 cases. The long-term stability of Herbst appliance was analyzed by 11 indexes of SNA, SNB, ANB, ANS-PNS/SN, MP/SN, ANS-PNS/MP, OB, OJ, U1/ANS-PNS, L1/MP, U1/L1. The results showed that SNA, SNB, ANB, ANS-PNS/SN, U1/ANS-PNS, L1/MP, molar relationships were stable in the long run from the end of treatment to follow-up ( $P>0.05$ ). The MP/SN, ANS-PNS/MP angles decrease, and the OB, OJ, and U1/L1 values increase ( $P<0.05$ ). **Conclusion:** The long-term stability of the treatment effect of Herbst orthoses in the adolescent patients classified as Class II division 1 shows that the relative position of the upper and lower jaws is relatively stable, while the Angle of the mandibular plane relative to the anterior skull base plane remains relatively unstable.

**Keywords:** Class II division1, Herbst appliance, long-term stability, systematic review, meta-analysis

## 1. Introduction

According to a 2000 survey conducted by the Orthodontic Committee of the Chinese Medical Association on the prevalence of malformations among 25,392 children and adolescents in seven

regions of China, the results are as follows: 51.84% in the deciduous stage, 71.21% in the replacement stage, and 72.92% in the early stage of permanent teeth (Fu Minkui & Zhang Ding et al., 2002). In recent years, parents have paid

more and more attention to the problem of malformation in children and adolescents, and for adolescents and children, the long-term stability of treatment results after orthodontic treatment is a direction that we need to focus on. The efficacy of Herbst appliances in the treatment of Angle class II division 1 malocclusion has been affirmed by many researchers. Although there is a certain amount of literature on the long-term stability of Herbst in the treatment of malformations in children and adolescents (Wieslander 1993; Chaiyongsirisern, Rabie et al., 2009; Austin, Chaiyongsirisern et al., 2010; Bock, von Bremen et al., 2010; Wigal, Dischinger et al., 2011; Drks, 2014; Bock, Gnandt et al., 2016; Bock, Saffar et al., 2018; de Arruda Aidar & Marchi et al., 2023), there is no relevant literature to evaluate and analyze these data as a whole. This study is the first article to evaluate the long-term stability of Herbst in the treatment of adolescent Angle class II division 1 malocclusion.

## 2. Materials and Methods

This study followed the PRISMA reporting specification for literature retrieval, quality evaluation, data analysis and thesis writing. The study protocol was written according to the PICOS principles and registered in PROSPERO (<https://www.crd.york.ac.uk/PROSPERO/>). Registration number: CRD42023472714.

### 2.1 Inclusion and Exclusion Criteria

A total of 12 studies with a total sample size of 490 cases were included. Inclusion Criteria: (1) Angle class II division 1 malocclusion; (2) permanent dentition/mixed dentition; (3) the age at which treatment was started was adolescents/children; (4) Herbst appliance treatment; (5) Long-term follow-up observation

≥ 2 years. Exclusion Criteria: (1) Non- Angle class II division 1 malocclusion; (2) adult orthodontic treatment; (3) There was no long-term follow-up observation ≥ 2 years.

### 2.2 Literature Search Strategy

Databases searched included: CNKI, WANFANG, VIP, CBM, PubMed, Embase, Cochrane Library. From the database, using keywords such as “Angle class II division 1 Malocclusion, mandibular retraction, Herbst appliances, stability, long-term, Angle Class II Malocclusion, Herbst functional appliance, relapse, retention, stability, post treatment, long term”, We searched all relevant articles up to August 2023 as comprehensively as possible.

### 2.3 Literature Review Screening

Two researchers independently screened the literature retrieved in the database, preliminarily screened the literature by reading the title and abstract, downloaded the screened literature, read the full text, further screened according to the inclusion criteria and exclusion criteria, and sought third-party opinions if there was any disagreement. The basic contents of literature extraction included: authors, names, year of publication, study type, gender, age, course of treatment, follow-up time, number of cases, interventions, outcome indicators, etc.

### 2.4 Literature Quality Evaluation

Two researchers evaluated the quality of non-randomized controlled trials according to the MINORS evaluation form, and the evaluation results were expressed as high-quality, moderate-quality, and low-quality. The specific content of the MINORS evaluation items is as follows (Table 1):

**Table 1.** MINORS Evaluation Items

Evaluation items	Evaluate the content
1. The purpose of the study is clearly given	The question defined should be precise and relevant to the available literature
2. Inclusion of patient coherence	All patients with potential (meeting the inclusion criteria) were included during the study (no exclusion or reasons given for exclusion)
3. Collection of expected data	Data were collected according to the data set out in the study protocol developed prior to the start of the study

4. Endpoint indicators appropriately reflect the purpose of the study	Clearly explain the criteria used to evaluate outcomes that are consistent with the question defined. At the same time, endpoint measures should be assessed on the basis of intention-to-treat analysis
5. Objectivity of endpoint evaluation	The reviewer's single-blind method was used for the evaluation of objective endpoint indicators, and the reviewer's double-blind method was used for the evaluation of subjective endpoint indicators. Otherwise, the reason for not performing a blinded evaluation should be given
6. Adequate follow-up time	Follow-up should be long enough to allow for an assessment of endpoints and possible adverse events
7. Loss to follow-up rate less than 5%	All patients should be followed up. Otherwise, the proportion lost to follow-up cannot exceed the proportion of patients reflecting the primary endpoint
8. Whether the sample size was estimated	Based on the incidence of expected outcome events, sample sizes and 95% confidence intervals (CIs) were calculated for different outcomes. The information provided allows for a comparison of expected and actual results with the level of estimated power from statistical differences
9~12 additional criteria for evaluating studies with a control group	
9. Whether the control group was appropriately selected	For diagnostic tests, should be the "gold standard" for diagnosis; For therapeutic intervention trials, the best intervention that can be extracted from published studies should be available
10. Whether the control group was synchronized	The control group should be conducted at the same time as the experimental group (non-historical control)
11. Whether baselines are comparable between groups	Unlike the study endpoints, the baseline criteria for the start of the control group and the experimental group should be similar. There were no confounding factors that could bias the interpretation of the results
12. Whether the statistical analysis is appropriate	Whether the statistics used to calculate confidence intervals or relative risk (RR) matched the type of study

### 2.5 Literature Data Extraction

Finally, 12 indicators, including SNA, SNB, ANB, ANS-PNS/SN, MP/SN, ANS-PNS/MP, OB, OJ,

U1/ANS-PNS, L1/MP, U1/L1 and molar relationship, were selected for meta-analysis. (Tables 2 and 3)

**Table 2. Bone Indicators**

Author and Year	Total number of people	SNA(°)				SNB(°)				ANB(°)			
		after treatment		follow-up		after treatment		follow-up		after treatment		follow-up	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Hans Pancherz 2015	14	82.2	4.56	81.5	5.25	76.9	4.02	77.4	4.72	5.3	1.85	4.4	1.86
Ken Hansen 1991(1)	19	80.8	3.8	81.6	3.8	76.4	3.5	77.8	3.4	4.3	2.1	3.9	2.2
Ken Hansen 1991(2)	15	80.9	3.4	81.2	3.9	77	3	77.8	3.2	3.9	1.3	3.4	1.4
Ken Hansen 1991(3)	6	82.6	2.7	82.9	3.2	78.6	3.8	79.2	4.3	4	2	3.6	2.5
Ken Hansen 1992	32	81	3.1	81.2	3.4	76.9	3.1	77.3	3.5	4.1	1.5	3.9	1.7
Ken Hansen, DDS, Odont.Dr. 1997	24	81.1	3.7	80.8	3.8	77.8	3.2	77.9	3.2	3.4	1.9	3	1.5
Kok Leong Dale Phan 2006	16	82.1	4.71	82.9	4.44	78.2	3.79	78.8	3.77	3.9	2.36	4.1	2.6
Luís Antônio de Arruda Aidar 2023	25	81.8	3.8	81.7	3.8	76.7	3.2	76.6	3.2	5.09	1.5	5.06	1.5
Niko Bock 2006	11	74	1.45	73.8	2.17	71.2	1.41	70.6	2.22	2.8	1.43	3.2	1.44

**Table 2. Continued**

Author and Year	Total number of people	ANS-PNS/SN(°)				MP/SN(°)				ANS-PNS/MP(°)			
		after treatment		follow-up		after treatment		follow-up		after treatment		follow-up	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Hans Pancherz 2015	14	30.5	6.71	28	7.23								
Ken Hansen 1991(1)	19	8.4	2.1	7.9	3	32.2	5.5	27.6	6.7	23.9	5.4	19.7	6.1
Ken Hansen 1991(2)	15	8	3.3	7.5	4.2	31.3	6.7	27.9	7.8	23.3	5.4	20.3	6.5
Ken Hansen 1991(3)	6	6.8	2.8	6.3	3.4	27.6	6.4	25.5	7.8	20.8	5.6	19.2	6.8

Ken Hansen 1992	32	8.2	3.1	7.9	3.1	30.6	6.3	28.2	7.3	22.4	5.5	20.4	6.4
Ken Hansen, DDS, Odont.Dr. 1997	24	8.2	2.9	8.3	2.5	32.4	5.4	29.8	5.2	24.2	4.2	21.4	4.2
Kok Leong Dale Phan 2006	16												
Luís Antônio de Arruda Aidar 2023	25												
Niko Bock 2006	11	12.8	3.09	12.5	2.91	42	3.76	41.1	4.73	29.2	5.15	28.6	5.35

**Table 3. Dental Indicators**

Author and Year	Total number of people	OB(mm)		OJ(mm)		Molar relationship(cw)							
		after treatment		follow-up		after treatment		follow-up		after treatment		follow-up	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Hans Pancherz 2015	14	3.5	1.06	3.8	0.83	3.9	0.89	4.2	1.67				
Ken Hansen 1991(1)	19												
Ken Hansen 1991(2)	15												
Ken Hansen 1991(3)	6												
Ken Hansen 1992	32	3.9	1.4	4.4	1.4	3.5	1.3	4.1	1	-2.6	1.4	-2.2	0.9
Ken Hansen, DDS, Odont.Dr. 1997	24												
Kok Leong Dale Phan 2006	16	2.9	1.66	3.2	1.89	4	2.22	4.2	2.15	-3	2.6	-3.3	2.67
Luís Antônio de Arruda Aidar 2023	25												
N.Bock 2018	240	1.5	0.89	2	1.13	2	0.91	2.7	0.93				
Niko Bock 2006	11					-0.6	2.11	3.2	0.64				
Niko C.Bock 2018	52	1.3	0.72	2.8	1.55	2.3	0.74	3.6	1.08	0	0.14	0	0.18
Niko Christian Bock 2023	10	1.4	0.4	2.5	1.1	2.3	0.4	3.1	0.4				
Hans Pancherz 2014	14									0	0.15	0.2	0.3

**Table 3. Continued**

Author and Year	Total number of people	U1/ANS-PNS(°)				L1-MP(°)				U1/L1(°)			
		after treatment		follow-up		after treatment		follow-up		after treatment		follow-up	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD

Hans Pancherz 2015	14					104	5.33	102	6.29	131	7.15	132,9	9.4
Ken Hansen 1991(1)	19	110	4.8	110	5.3	103	6.8	104	7.8	123	5.7	127	8.9
Ken Hansen 1991(2)	15	107	7.6	107	7.9	102	4.7	102	6.7	128	7.2	131	9.6
Ken Hansen 1991(3)	6	106	6.8	106	5.9	107	8.9	107	9.1	126	8.4	128	8.8
Ken Hansen 1992	32	107	6	106	6.6	104	6.6	104	7.1	127	7.6	129	9.3
Ken Hansen, DDS, Odont.Dr. 1997	24	106	5.9	110	6	109	6.2	101	7.3				
Kok Leong Dale Phan 2006	16												
Luís Antônio de Arruda Aidar 2023	25	112	6.18	112	7.01	107	5.92	103	8.31				
N.Bock 2018	240												
Niko Bock 2006	11												
Niko C.Bock 2018	52												
Niko Christian Bock 2023	10												
Hans Pancherz 2014	14												

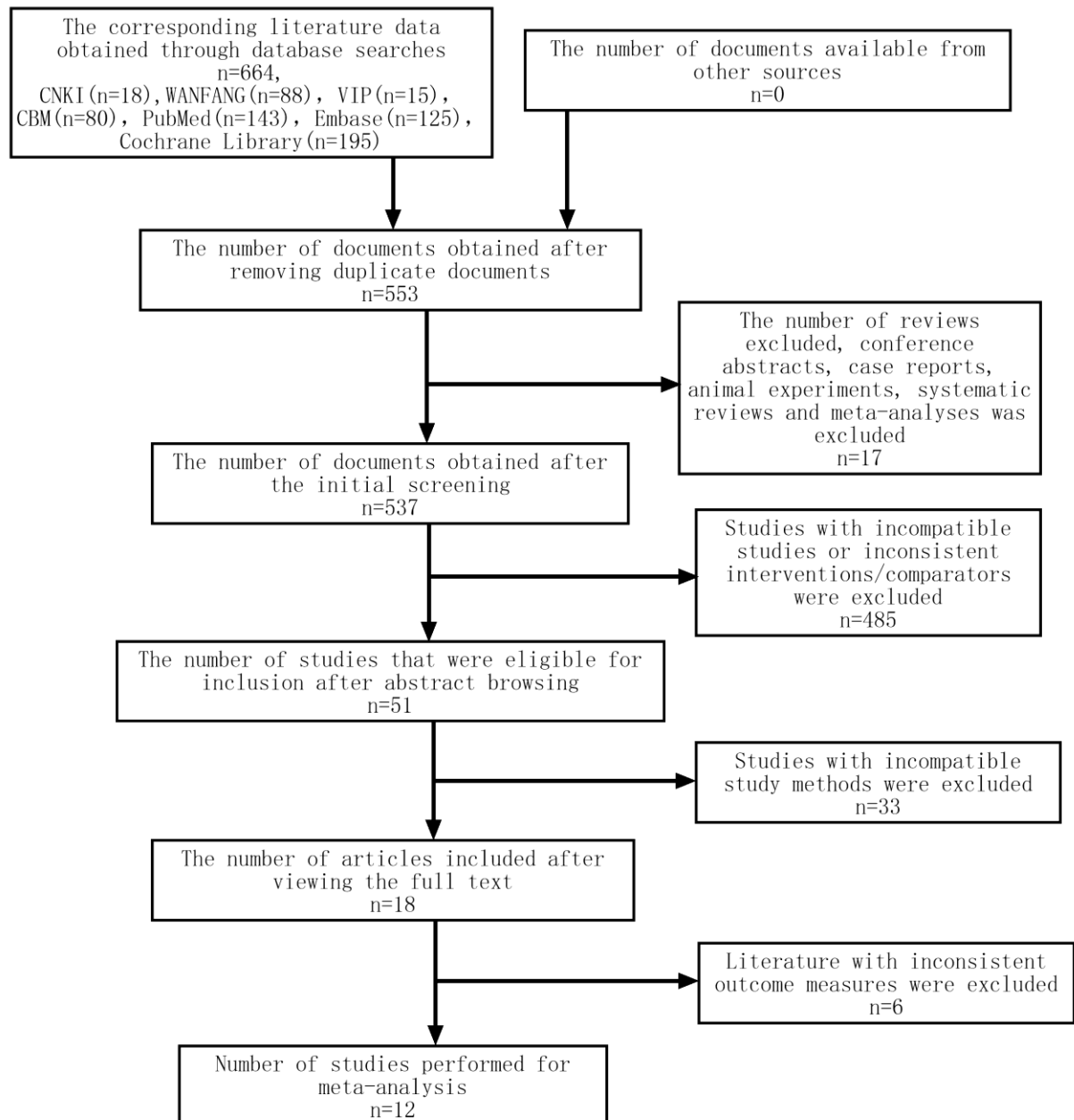
## 2.6 Statistical Analysis

RevMan 5.3 software was used for statistical analysis. The data in this study were continuous and were expressed as mean differences with 95% confidence intervals.  $I^2$  was used for heterogeneity testing, and if heterogeneity between groups was low or absent ( $P \geq 0.1$  or  $I^2 \leq 50\%$ ), a fixed-effect model was used for meta-analysis; If there was moderate heterogeneity between groups ( $50\% < I^2 < 75\%$ ), the source of heterogeneity was explained and a random-effects model was used for meta-analysis; Subgroup analyses were used if there was a high degree of heterogeneity between groups ( $I^2 \geq 75\%$ ), and only descriptive analyses were performed if the source of heterogeneity could not be determined.

## 3. Results

### 3.1 Literature Search Results

A total of 664 Chinese and English articles (18 CNKI, 88 WANFANG, 15 VIP, 80 CBM, 143 PubMed, 125 Embase, and 195 Cochrane Library) were retrieved in the initial examination, 553 articles were retained after the duplicate literature was eliminated, 51 articles were retained after reading the abstract of the remaining literature, 51 articles were retained after excluding irrelevant literature, and the remaining 51 articles were read in full, and 12 articles that met the inclusion criteria were finally screened out (Figure 1).



**Figure 1.** Literature Screening Flowchart

### 3.2 The Quality of the Included Literature

included literature are shown below (Table 4).

The results of the quality evaluation of the

**Table 4.** Literature Quality Evaluation Form

MINORS Score Author Year	Evaluation Items 1	Evaluation Items 2	Evaluation Items 3	Evaluation Items 4	Evaluation Items 5	Evaluation Items 6
Luís Antônio de Arruda Aida 2023	2	2	2	2	0	2
Niko Christian Bock 2023	2	2	2	2	1	2
Niko C.Bock 2018	2	2	2	2	0	2

N. Bock 2018	2	2	2	2	2	2
Niko C. Bock 2016	2	2	2	2	1	2
Hans Pancherz 2015	2	2	2	2	0	2
Hans Pancherz 2014	2	2	2	2	0	2
Niko Bock 2006	2	2	2	2	0	2
Kok Leong Dale Phan 2006	2	2	2	2	0	2
Ken Hansen, DDS, Odont. Dr. 1997	2	2	2	2	0	2
Ken Hansen 1992	2	2	2	2	0	2
Ken Hansen 1991	2	2	2	2	0	2

**Table 4.** Literature Quality Evaluation Form (Continued)

MINORS Score Author Year	Evalua- -tion Items 7	Evalua- -tion Items 8	Evalua- -tion Items 9	Evalua- -tion Items 10	Evalua- -tion Items 11	Evalua- -tion Items 12	MINORS Total Score
Luís Antônio de Arruda Aidar 2023	1	1	1	2	1	2	18
Niko Christian Bock 2023	1	1	1	2	1	1	18
Niko C.Bock 2018	0	1	1	2	1	2	17
N. Bock 2018	2	1					15
Niko C. Bock 2016	2	1	1	1	2	1	19
Hans Pancherz 2015	1	1					12
Hans Pancherz 2014	1	1					12
Niko Bock 2006	1	1	1	2	1	1	17
Kok Leong Dale Phan 2006	2	1					13
Ken Hansen, DDS, Odont. Dr. 1997	2	1	1	2	2	1	19
Ken Hansen 1992	1	1	1	2	2	1	18
Ken Hansen 1991	2	1	1	2	2	1	19

High-quality literature (17-24 points): 8 articles;  
Moderate-quality literature (9-16 points): 4 articles.

### 3.3 Characteristics of the Included Literature

Included patients: The average age of the included patients was in the range of 12-15 years, and most of them were in or around the peak

growth period. Disease type and treatment: The patients were all patients with Angle class II division 1 malocclusion and were treated with Herbst appliances. Follow-up time: The minimum follow-up time was 2 years and the maximum follow-up time was 32 years (Table 5).



**Table 5.** Basic Characteristics of the Included Literature

Luís António de Arruda Aidar	2023	Herbst	Angle II division 1	25	12.78±1.15 years	4 years
Niko Christian Bock	2023	Herbst	Angle II division 1	10	14.7±1.4 years	≥15 years
Niko C.Bock	2018	Herbst	Angle II division 1	52	12.8±2.65 years	18.3±3.12 years
N. Bock	2018	Herbst	Angle II division 1	240	14.4±3.4 years	32.7±15.93months
Niko C. Bock	2016	Herbst	Angle II division 1	11	14.6±2.07 years	31.1 months
Hans Pancherz	2015	Herbst	Angle II division 1	14	12.5 years	32years
Hans Pancherz	2014	Herbst	Angle II division 1	14	12.5 years	32years
Niko Bock	2006	Herbst	Angle II division 1	11	15 years (range 11 to 18 years)	39 months (range 26 to 61 months)
Kok Leong Dale Phan	2006	Herbst	Angle II division 1	17	12.9±1.3 years	2 years
Ken Hansen, DDS, Odont. Dr.	1997	Herbst	Angle II division 1	24	13.0±1.3 years	6.5±1.1 years
Ken Hansen	1992	Herbst	Angle II division 1	32	12.5±1.0 years	6.8±1.1 years
Ken Hansen	1991	Herbst	Angle II division 1	19	12.24±0.69 years	7.58±0.56 years
Ken Hansen	1991	Herbst	Angle II division 1	15	12.9±0.60 years	6.81±1.11 years
Ken Hansen	1991	Herbst	Angle II division 1	6	14.16±1.10 years	7.15±1.05 years

The number of studies that met the inclusion criteria was small and the sample size was predominantly small, so the data needed to be interpreted in detail.

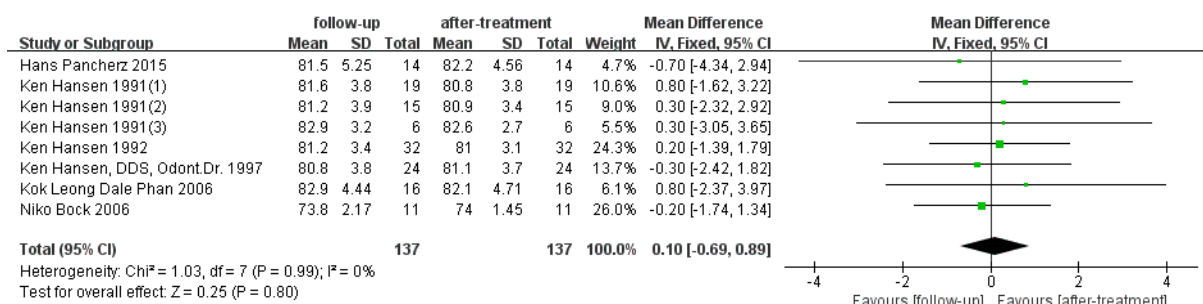
### 3.4 Results of Meta-Analysis

Meta-analysis was performed for changes in SNA, SNB, ANB, ANS-PNS/SN, MP/SN, ANS-PNS/MP, OB, OJ, U1/ANS-PNS, L1/MP, U1/L1 and Molar relationship after the end of orthodontic treatment and long-term maintenance, and these 12 indicators were the most widely used indicators in the retrieved literature.

#### 3.4.1 Bone Indictors

SNA: is the angle formed by the center of the

sella, the root of the nose and the seat of the upper alveolar seat, which reflects the anterior-posterior position of the maxilla relative to the cranium (Zhao Zhihe, 2020). Eight groups of data were analyzed to analyze the changes in SNA angle after treatment and after a period of follow-up (Hansen, Pancherz et al., 1991; Hansen & Pancherz, 1992; Hansen, Koutsonas et al., 1997; Bock & Pancherz 2006; Phan, Bendeus et al., 2006; Pancherz, Bjerklin et al., 2015) (Figure 2), and the heterogeneity test ( $I^2 = 0\%$ ) showed that there was no heterogeneity between groups, and the results showed that there was no significant difference in SNA angle after treatment and after a period of follow-up [MD=0.1, 95%CI (-0.69, 0.89),  $P=0.80$ ].



**Figure 2.** Forest Plot of SNA

SNB: The angle formed by the center of the sella, the base of the nose and the lower alveolar seat. Reflects the position of the lower jaw relative to the cranial region (Zhao Zhihe, 2020). Eight groups of data were analyzed to analyze the

changes in SNB angles after treatment and after a period of follow-up (Hansen, Pancherz et al., 1991; Hansen & Pancherz, 1992; Hansen, Koutsonas et al., 1997; Bock & Pancherz, 2006; Phan, Bendeus et al., 2006; Pancherz, Bjerklin et

al., 2015) (Figure 3), and the heterogeneity test ( $I^2 = 0\%$ ) showed that there was no heterogeneity between groups, and the results showed that

there was no significant difference in SNB angles after treatment and after a period of follow-up [MD=0.27, 95%CI (-0.50, 1.04),  $P=0.50$ ].

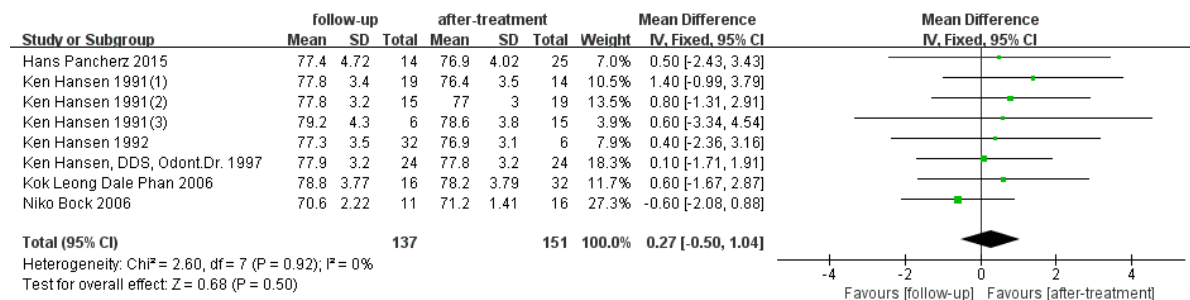


Figure 3. Forest Plot of SNB

ANB: is the angle formed by the upper alveolar seat point, the root point of the nose and the lower alveolar seat point, which is the difference between the SNA angle and the SNB angle. This horn reflects the relative position of the upper and lower jaws to the cranium (Zhao Zhihe, 2020). Eight groups of data were analyzed to analyze the changes in SNB angles after treatment and after a period of follow-up (Hansen, Pancherz et al., 1991; Hansen &

Pancherz, 1992; Hansen, Koutsonas et al., 1997; Bock & Pancherz, 2006; Phan, Bendeus et al., 2006; Pancherz, Bjerklin et al., 2015) (Figure 4), and the heterogeneity test ( $I^2 = 0\%$ ) showed that there was no heterogeneity between groups, and a fixed-effect model was used to analyze the ANB angles, and the results showed that there was no significant difference in ANB angles after treatment and after a period of follow-up [MD=-0.28, 95%CI (-0.69, 0.13),  $P=0.18$ ]

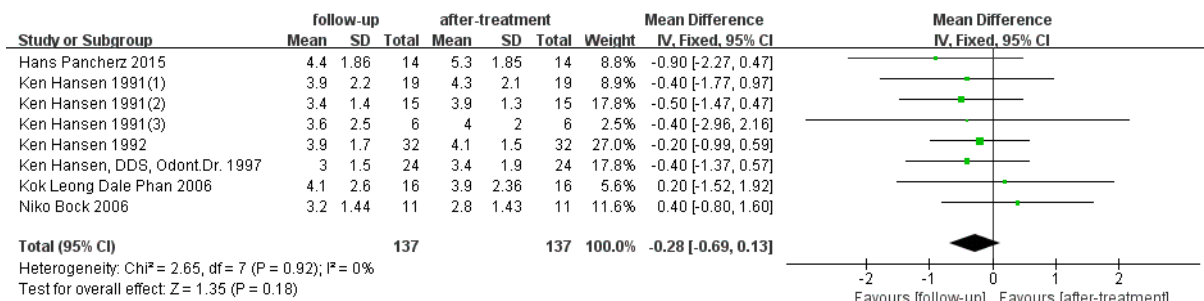


Figure 4. Forest Plot of ANB

ANS-PNS/SN: is the angle between the palatal plane and the anterior skull base plane. Seven groups of data were analyzed to analyze the changes in ANS-PNS/SN angles after treatment and after a period of follow-up (Hansen, Pancherz et al., 1991; Hansen & Pancherz, 1992; Hansen, Koutsonas et al., 1997; Bock & Pancherz 2006; Phan, Bendeus et al., 2006; Pancherz,

Bjerklin et al., 2015) (Figure 5), and the heterogeneity test ( $I^2 = 0\%$ ) showed that there was no heterogeneity between groups, and the results showed that there was no significant difference in ANS-PNS/SN angles after treatment and after a period of follow-up [MD=-0.32, 95%CI (-1.10, 0.46),  $P=0.42$ ]

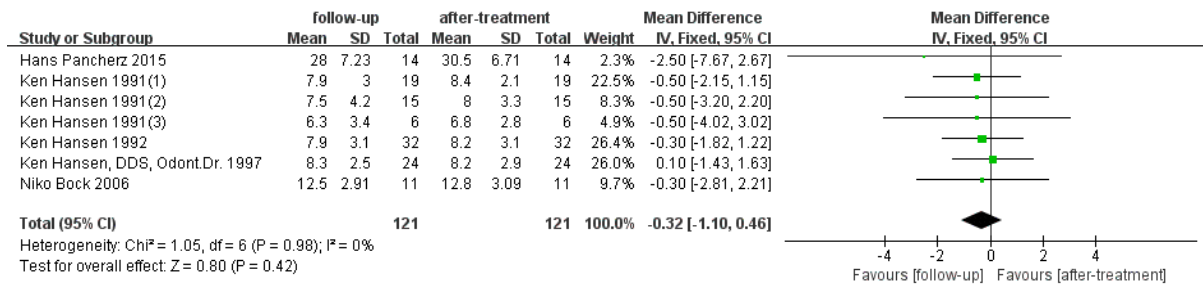


Figure 5. Forest Plot of ANS-PNS/SN

MP/SN: is the angle between the mandibular plane and the anterior skull base plane.

The data of 6 groups analyzed the changes in MP/SN angle after treatment and after a period of follow-up (Hansen, Pancherz et al., 1991; Hansen & Pancherz, 1992; Hansen, Koutsonas et al., 1997; Bock & Pancherz, 2006) (Figure 6), and the heterogeneity test (I<sup>2</sup> = 0%), indicating that

there was no heterogeneity between groups, and the fixed-effect model was used for analysis, and the results showed that there was a statistically significant difference in MP/SN angle after treatment and after a period of follow-up [MD = -2.61, 95%CI (-4.19, -1.02), P = 0.001], and the MP/SN angle showed a decreasing trend.

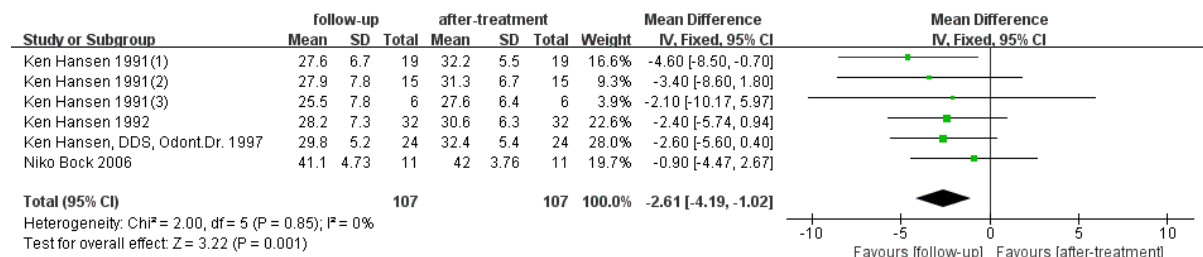


Figure 6. Forest Plot of MP/SN

ANS-PNS/MP: is the angle between the palatal plane and the mandibular plane. The six groups were analyzed to analyze the changes in ANS-PNS/MP angle after treatment and after a period of follow-up (Hansen, Pancherz et al., 1991; Hansen & Pancherz, 1992; Hansen, Koutsonas et al., 1997; Bock & Pancherz, 2006) (Figure 7), and the heterogeneity test (I<sup>2</sup> = 0%)

showed that there was no heterogeneity between groups, and the results showed that there was a statistically significant difference in ANS-PNS/MP angle after treatment and after a period of follow-up [MD = -2.56, 95%CI (-3.99, -1.14), P = 0.0004]. The ANS-PNS/MP angle tends to decrease.

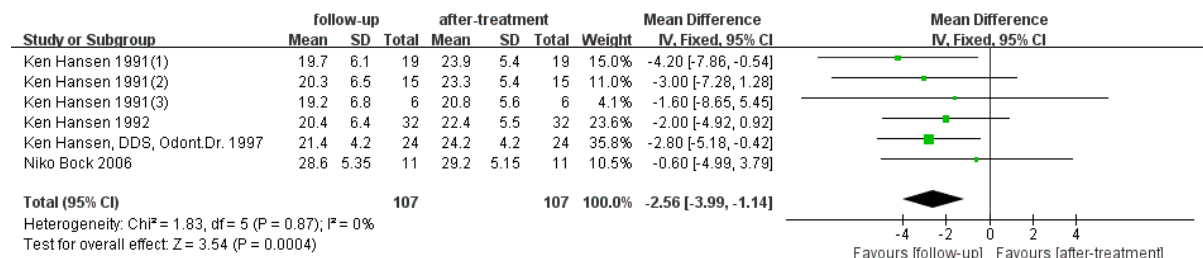


Figure 7. Forest Plot of ANS-PNS/MP

### 3.4.2 Dental Indicators

OB: Refers to the vertical distance between the

upper anterior teeth covering the labial surface of the lower anterior teeth, and the overlapping condition in the vertical direction represents the

anterior tooth relationship (Zhao Zhihe, 2020). The data of 7 groups analyzed the changes in OB values after treatment and after a period of follow-up (Hansen & Pancherz, 1992; Phan, Bendeus et al., 2006; Pancherz, Bjerklin et al., 2015; Bock, Gndant et al., 2016; Bock, Ruehl et al., 2018; Bock, Saffar et al., 2018; Bock, Jungbauer et al., 2023) (Figure 8), and the

heterogeneity test ( $I^2=67\%$ ), indicating that there was heterogeneity between groups, and the results showed that the difference in OB values after treatment and after a period of follow-up was statistically significant [MD=0.73, 95%CI (0.32, 1.15),  $P=0.005$ ], and the OB values showed an increasing trend.

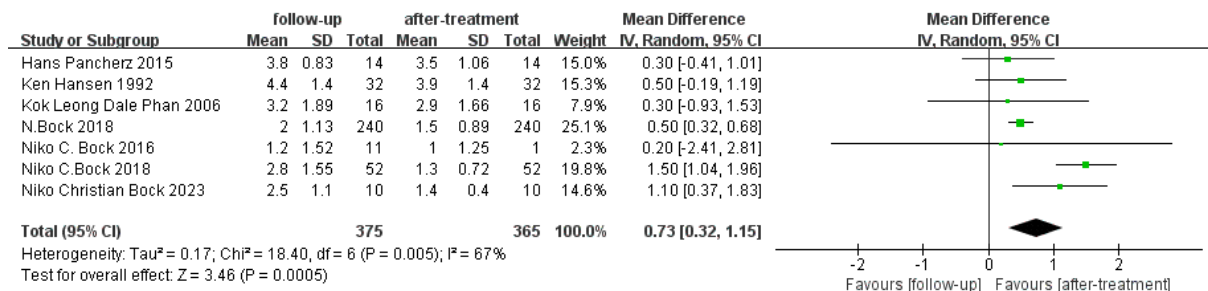


Figure 8. Forest Plot of OB

OJ: refers to the horizontal distance between the upper anterior teeth and the lower anterior teeth, and the horizontal distance from the incisal edge of the upper incisor to the labial surface of the lower incisor (Zhao Zhihe, 2020). The 8 groups analyzed the changes in OJ values after treatment and after a period of follow-up (Hansen & Pancherz, 1992, Bock & Pancherz 2006; Phan, Bendeus et al., 2006; Pancherz, Bjerklin et al., 2015; Bock, Gndant et al., 2016;

Bock, Ruehl et al., 2018; Bock, Saffar et al., 2018; Bock, Jungbauer et al., 2023) (Figure 9), heterogeneity test ( $I^2=78\%$ ), indicating that there was heterogeneity between groups, and the analysis was carried out using a random-effects model, and the results showed that the difference in OJ value after treatment and after a period of follow-up was statistically significant [MD=0.94, 95%CI (0.55, 1.33),  $P<0.00001$ ], and the OJ value showed an increasing trend.

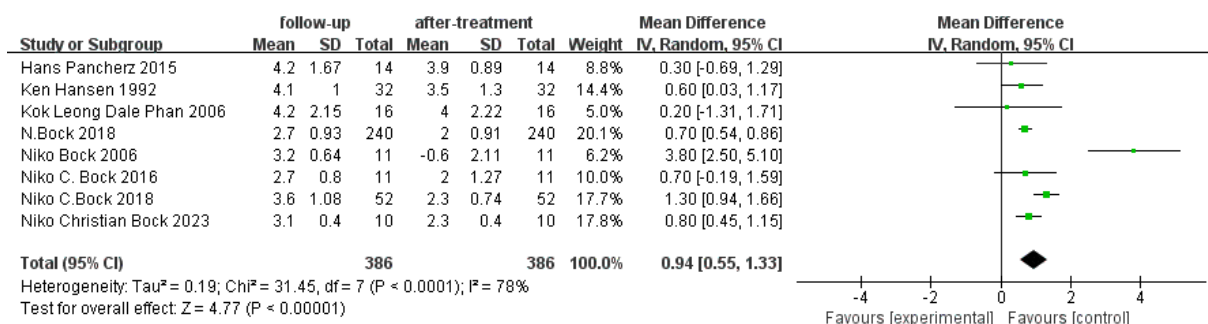


Figure 9. Forest Plot of OJ

U1/ANS-PNS: is the inferior medial angle where the long axis of the upper middle incisor intersects with the palatal plane, reflecting the relative inclination of the upper incisor relative to the palatal plane. The six groups analyzed the changes in U1/ANS-PNS angle after treatment and after a period of follow-up (Hansen, Pancherz et al., 1991, Hansen & Pancherz, 1992,

Hansen, Koutsonas et al., 1997, de Arruda Aidar, Marchi et al., 2023) (Figure 10), heterogeneity test ( $I^2=14\%$ ), indicating that there was no heterogeneity between groups, and the results showed that there was no statistically significant difference in U1/ANS-PNS angle after treatment and after a period of follow-up [MD=0.56, 95%CI (-1.00, 2.11),  $P=0.48$ ].

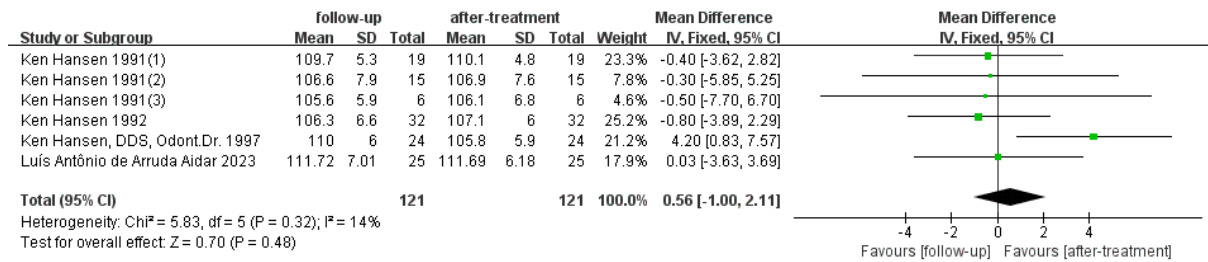


Figure 10. Forest Plot of U1/ANS-PNS

L1/MP: is the upper medial angle where the long axis of the lower central incisor intersects with the mandibular plane. Reflects the inclination of the lower central incisor relative to the mandibular plane (Zhao Zhihe, 2020). Seven groups were analyzed to analyze the changes in L1/MP angle after treatment and after a period of follow-up (Hansen, Pancherz et al., 1991; Hansen &Pancherz, 1992; Hansen, Koutsonas et

al., 1997; Pancherz, Bjerklín et al., 2015; de Arruda Aidar, Marchi et al., 2023) (Figure 11), heterogeneity test (I<sup>2</sup> =58%), indicating that there was heterogeneity between groups, and the results showed that there was no statistically significant difference in L1/MP angle after treatment and after a period of follow-up [MD=-2.20, 95%CI (-4.77, 0.37), P=0.09]

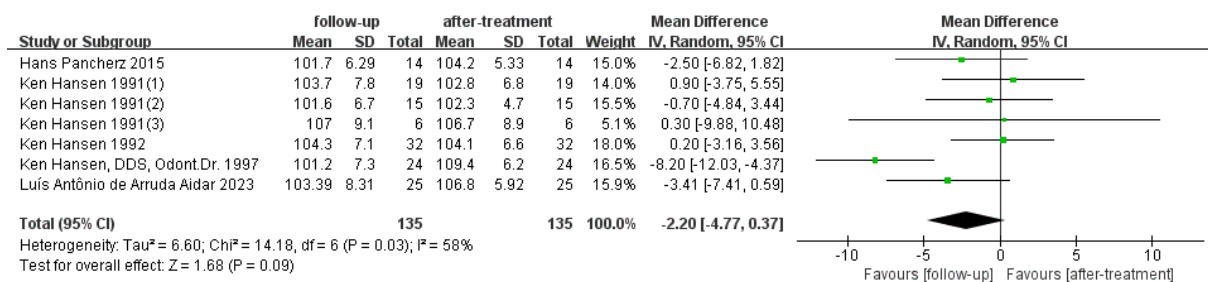


Figure 11. Forest Plot of L1/MP

U1/L1: is the angle of intersection between the long axis of the upper central incisor and the lower central incisor, reflecting the convexity of the upper and lower central incisors, especially the arches of the upper and lower anterior teeth (Zhao Zhihe, 2020). The data of the five groups analyzed the changes in U1/L1 angle after treatment and after a period of follow-up (Hansen, Pancherz et al., 1991; Hansen &

Pancherz, 1992; Pancherz, Bjerklín et al., 2015) (Figure 12), and the heterogeneity test (I<sup>2</sup> =0%) showed that there was no heterogeneity between groups, and the results showed that the difference in U1/L1 angle after treatment and after a period of follow-up was statistically significant [MD=2.98, 95%CI (0.53, 5.44), P=0.02], and U1/L1 showed an increasing trend.

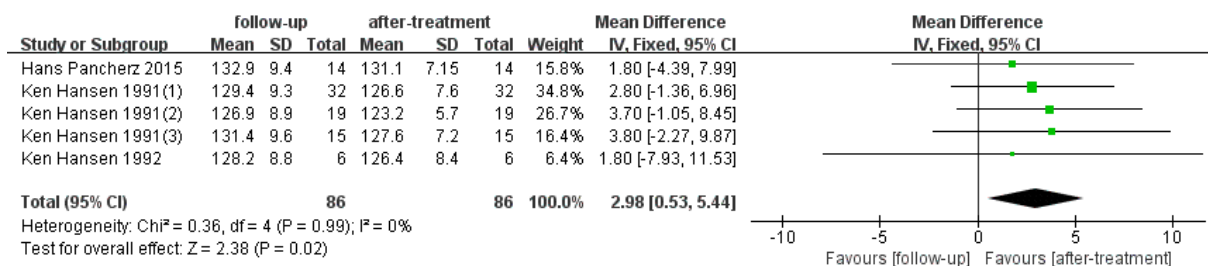


Figure 12. Forest Plot of U1/L1

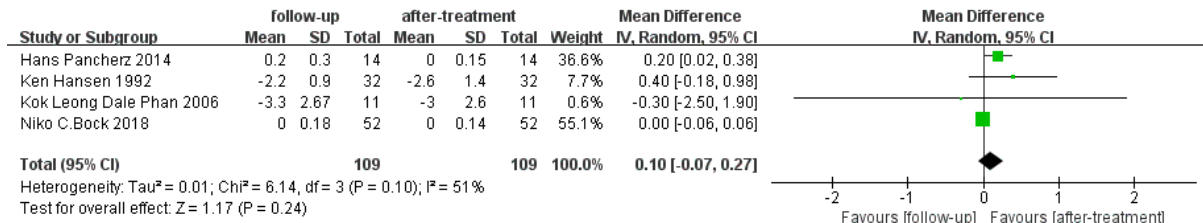
Molar relationship: It is a sagittal relationship of

molars. The four groups analyzed the changes in



the molar relationship after treatment and after a period of follow-up (Hansen & Pancherz, 1992; Phan, Bendeus et al., 2006; Pancherz & Bjerklin 2014; Bock, Saffar et al., 2018) (Figure 13), and the heterogeneity test ( $I^2 = 51\%$ ) showed that

there was heterogeneity between groups, and the results showed that there was no statistically significant difference in the molar relationship between treatment and follow-up [MD=0.10, 95%CI (-0.07, 0.27),  $P=0.24$ ].



**Figure 13.** Forest Plot of Molar Relationship

#### 4. Discussion

In this study, we conducted a meta-analysis of the changes in various indicators after the end and long-term maintenance of the Herbst appliance to evaluate the long-term stability of the Herbst appliance in the treatment of Angle's class II division 1 malocclusion, in which randomized clinical trials are rarely used for the following reasons: it is difficult to accurately define the type and characteristics of the malformation in theory; Ethical issues, for patients to be classified as a control group means that they may not receive the most advanced or correct treatment, so the patient refuses to participate in the control group; There is a risk of data loss in long-term follow-up studies (Osama, Huang Yurong et al., 2019). Therefore, the literature included in this study was a retrospective study, and there were no randomized clinical trials (RCTs) for these observational studies.

The 12 included literatures (Hansen, Pancherz et al., 1991; Hansen and Pancherz, 1992; Hansen, Koutsonas et al., 1997; Bock & Pancherz, 2006; Phan, Bendeus et al., 2006; Pancherz, Bjerklin et al., 2014; Pancherz, Bjerklin et al., 2015; Bock, Gnandt et al., 2016; Bock, Ruehl et al., 2018; Bock, Saffar et al., 2018; de Arruda Aidar, Marchi et al., 2023) reported the changes of 12 indexes of SNA, SNB, ANB, ANS-PNS/SN, MP/SN, ANS-PNS/MP, OB, OJ, U1/ANS-PNS, L1/MP, U1/L1, and molar relationship after treatment and follow-up. The results of meta-analysis included 12 indicators: SNA, SNB, ANB, ANS-PNS/SN, MP/SN, ANS-PNS/MP, OB, OJ, U1/ANS-PNS, L1/MP, U1/L1, and molar relationship.

##### 4.1 Analysis of Outcome Measures

The results of meta-analysis showed that there was no statistical significance in the changes of SNA, SNB and ANB in the bony structure after a period of follow-up, and we could consider that the relative position adjustment of the upper and lower jaws was relatively stable after treatment with Herbst appliances. There was no statistically significant change in ANS-PNS/SN results, and we can assume that the palatal plane position remained relatively stable after treatment with Herbst appliances. After a period of follow-up, there was a statistically significant change in the results of MP/SN, ANS-PNS/MP, and we can conclude that after treatment with Herbst appliances, the position of the lower jaw plane remained relatively unstable, and the angle with the skull base plane and the palatal plane showed a trend of decreasing, according to the research results of a large number of scholars, for patients with class II class 1 classification, most of them belonged to the vertical growth type (Schulz, Koos et al., 2016; Knigge, Hardin et al., 2022), and the lower jaw had a tendency to grow in the direction of the open type. From this, we can infer that the functional appliance has a certain blocking and guiding effect on the patient's growth type during the treatment process, and after the treatment is over, the intervention is removed, and there is a certain tendency of rotation in the mandibular plane to the direction of the closed mouth type, that is, the opposite trend of the original growth type. Analysis of dental indexes: According to the results of meta-analysis, there was no statistical significance in the changes of U1/ANS-PNS, U1/ANS-PNS, L1/MP, and molar relationship after the end of treatment and follow-up for a period of time, and we believed that the position of the palatal plane, the

position of the upper central incisors, the position of the lower central incisors relative to the mandibular plane, and the sagittal relationship of the molars were in a relatively stable state after the end of treatment until a period of follow-up. After a period of follow-up, there was a statistically significant change in the numerical changes of U1/L1 and overlay coverage, and all of them showed an increasing trend, which may be related to the change of the mandibular plane.

#### 4.2 Limitations of This Study and Implications for Clinical Research

In this study, strict inclusion and exclusion criteria were formulated, and the quality of the included literature was strictly evaluated, but there were still the following limitations: (1) there was no randomized controlled trial in the included literature, which affected the quality of the study to a certain extent, but due to ethical issues and limitations of the research content, the most appropriate treatment method was needed to be given to the patients in clinical practice, and a control group could not be established, and long-term follow-up of the patients was required after the end of treatment, so the randomized control could not be realized; (2) This study only includes Chinese and English studies, and may omit relevant studies in other languages; (3) There were differences in the follow-up time after orthodontic treatment among the studies, which may lead to a certain degree of clinical heterogeneity between the results of the studies.

### 5. Conclusion

In terms of long-term stability, according to the results of this study, the relative position of the upper and lower jaws is relatively stable, and to a certain extent, the Herbst appliance has long-term stability in the early treatment of the relative relationship between the upper and lower jaws. Although the angle of the mandibular plane relative to the anterior skull base plane changed from the end of treatment to the follow-up period, it showed a tendency to rotate in the direction of the closed mouth, and we still believe that the Herbst appliance has long-term stability for Angle class II division 1 malocclusion. Whether there is a long-term effect of functional appliances on the blocking effect of mandibular growth, and whether the use of treatment methods can intervene in the growth of adolescents and children in the

process of orthodontic treatment, is the direction we need to pay attention to next.

### Fund Project

This work was supported by a grant from the Key Research and Development Program in Hebei Province of China (No.22377741D).

### References

- Austin, D. F., A. Chaiyongsirisern, Y. Yang, R. W. Wong and A. B. Rabie. (2010). "A protocol for improved stability with Herbst appliance treatment for adults." *Prog Orthod*, 11(2), 151-156.
- Bock, N. and H. Pancherz. (2006). "Herbst treatment of Class II division 1 malocclusions in retrognathic and prognathic facial types: A cephalometric long-term retrospective study." *Angle Orthodontist*, 76(6), 930-941.
- Bock, N. C., E. Gnandt and S. Ruf. (2016). "Occlusal stability after Herbst treatment of patients with retrognathic and prognathic facial types : A pilot study." *J Orofac Orthop*, 77(3), 160-167.
- Bock, N. C., J. von Bremen and S. Ruf. (2010). "Occlusal stability of adult Class II Division 1 treatment with the Herbst appliance." *Am J Orthod Dentofacial Orthop*, 138(2), 146-151.
- Bock, N. C., M. Saffar, H. Hudel, M. Evälahti, K. Heikinheimo, D. P. Rice and S. Ruf. (2018). "Long-term ( $\geq 15$  years) post-treatment changes and outcome quality after Class II:1 treatment in comparison to untreated Class I controls." *Eur J Orthod*, 40(2), 206-213.
- Bock, N. C., M. Saffar, H. Hudel, M. Evälahti, K. Heikinheimo, D. P. Rice and S. Ruf. (2018). "Outcome quality and long-term ( $\geq 15$  years) stability after Class II:2 Herbst-multibracket appliance treatment in comparison to untreated Class I controls." *Eur J Orthod* 40(5), 488-495.
- Bock, N. C., R. Jungbauer, I. Rudzki, P. Proff and S. Ruf. (2023). "Long-term ( $\geq 15$  years) outcome quality after Class II:1 bionator or Herbst multibracket appliance treatment : A comparison." *J Orofac Orthop*.
- Bock, N., J. Ruehl and S. Ruf. (2018). "Orthodontic Class II:1 treatment-efficiency and outcome quality of Herbst-multibracket appliance therapy." *Clin Oral Investig*, 22(5), 2005-2011.

- Chaiyongsirisern, A., A. B. Rabie and R. W. Wong. (2009). "Stepwise advancement Herbst appliance versus mandibular sagittal split osteotomy. Treatment effects and long-term stability of adult Class II patients." *Angle Orthod*, 79(6), 1084-1094.
- de Arruda Aidar, L. A., L. C. Marchi, S. Fuerte, H. K. Yamashita and G. C. Dominguez. (2023). "Evaluation of the stability of treatment with Herbst appliance associated with Hyrax expander and fixed orthodontics through counterpart analysis: A longitudinal follow-up study." *Orthod Craniofac Res*, 26(1), 27-36.
- Drks. (2014). "Long-term stability after Class II treatment with the Herbst appliance." <https://trialsearch.who.int/Trial2.aspx?TrialID=DRKS00006354>.
- Fu Minkui, Zhang Ding, Wang Bangkang, Deng Yan, Wang Fohan and Ye Xiangyu (2002). Prevalence of malformation in 25392 children and adolescents in China. *Orthodontics*, (04), 151-153.
- Hansen, K. and H. Pancherz. (1992). "Long-term effects of Herbst treatment in relation to normal growth development: a cephalometric study." *Eur J Orthod*, 14(4), 285-295.
- Hansen, K., H. Pancherz and U. Hägg. (1991). "Long-term effects of the Herbst appliance in relation to the treatment growth period: a cephalometric study." *Eur J Orthod*, 13(6), 471-481.
- Hansen, K., T. G. Koutsonas and H. Pancherz. (1997). "Long-term effects of Herbst treatment on the mandibular incisor segment: a cephalometric and biometric investigation." *Am J Orthod Dentofacial Orthop*, 112(1), 92-103.
- Knigge, R. P., A. M. Hardin, K. M. Middleton, K. P. McNulty, H. S. Oh, M. Valiathan, D. L. Duren and R. J. Sherwood. (2022). "Craniofacial growth and morphology among intersecting clinical categories." *The Anatomical Record*, 305(9), 2175-2206.
- Osama, Huang Yurong, Gong Xuyan, Hou Yuxia, Li Tong. (2019). A meta-analysis of the long-term stability of an ANSI Class II Class 1 dental extraction versus non-extraction. *Beijing Journal of Stomatology*.
- Pancherz, H. and K. Bjerklin. (2014). "Mandibular incisor inclination, tooth irregularity, and gingival recessions after Herbst therapy: a 32-year follow-up study." *Am J Orthod Dentofacial Orthop*, 146(3), 310-318.
- Pancherz, H., K. Bjerklin and K. Hashemi. (2015). "Late adult skeletofacial growth after adolescent Herbst therapy: a 32-year longitudinal follow-up study." *Am J Orthod Dentofacial Orthop*, 147(1), 19-28.
- Pancherz, H., K. Bjerklin, B. Lindskog-Stokland and K. Hansen. (2014). "Thirty-two-year follow-up study of Herbst therapy: a biometric dental cast analysis." *Am J Orthod Dentofacial Orthop*, 145(1), 15-27.
- Phan, K. L., M. Bendeus, U. Hägg, K. Hansen and A. B. Rabie. (2006). "Comparison of the headgear activator and Herbst appliance — effects and post-treatment changes." *Eur J Orthod*, 28(6), 594-604.
- Schulz, S., B. Koos, K. Duske and F. Stahl. (2016). "Skeletal effects in Angle Class II/1 patients treated with the functional regulator type II: cephalometric and tensor analysis." *Fortschritte der Kieferorthopädie [Journal of orofacial orthopedics]*, 77(6), 420-431.
- Wieslander, L. (1993). "Long-term effect of treatment with the headgear-Herbst appliance in the early mixed dentition. Stability or relapse?" *Am J Orthod Dentofacial Orthop*, 104(4), 319-329.
- Wigal, T. G., T. Dischinger, C. Martin, T. Razmus, E. Gunel and P. Ngan. (2011). "Stability of Class II treatment with an edgewise crowned Herbst appliance in the early mixed dentition: Skeletal and dental changes." *Am J Orthod Dentofacial Orthop*, 140(2), 210-223.
- Zhao Zhihe (2020). Orthodontics. People's Medical Publishing House, 13th Five-Year Plan — 7th Edition.