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Research Article

Dentoalveolar And Skeletal Effects Of Fixed Functional Appliances – A Systematic Review And Meta-Analysis

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ARTICLE INFO | **ABSTRACT**

Objective: To appraise the difference between treatment effects of fixed functional appliances (FFA) and untreated class II (UclII) malocclusion on skeletodental cephalometric measurements.
Material and Methods: Literature search was conducted across PubMed, MEDLINE, DOAJ, Cochrane Library, and Scopus until August 2023. Using MeSH and free text terms based on the PICOS framework with Boolean operators. Additional searches involved cross-referencing, citation chasing, and exploring grey literature through Google Scholar, Greylist, OpenGrey, and hand searching specialty journals.
Results: 16 studies were included. Studies assessing SNA revealed a pooled value of -0.44[-0.78, -0.11], indicating a (p=0.008) reduction in SNA values with FFA compared UclII. Mandibular changes reported a combined SNB value of -0.10[-0.43, 0.223], suggesting higher SNB with FFA vs UclII. ANB angle reported a notable decrease (-0.95[-1.79, -0.11], p=0.03) at 90% heterogeneity. Overjet displayed reduction (-2.08[-2.62, -1.54]mm) with 75% heterogeneity, while overbite, demonstrated a significant decrease (-1.08[-1.79, -0.37]mm) with 85% heterogeneity.
Conclusion: Analysis of 16 studies comparing the effects of Functional Appliance (FFA) and UclII revealed significant findings. Studies assessing SNA indicated a notable reduction in SNA values with FFA compared to UclII (p=0.008). Mandibular changes, particularly the SNB value, suggested higher values with FFA versus UclII. The ANB angle showed a significant decrease with FFA (p=0.03).

Keywords: Fixed Functional Appliance, Orthodontic Appliance Functional, Untreated Class II Malocclusion

1. INTRODUCTION

Class II Malocclusion is the most common form of malocclusion encountered in orthodontics with mandibular retrusion as its most common component [1] The available treatment options vary, including methods such as compensating for dentoalveolar issues, making orthopedic corrections using FFA, and resorting to orthognathic surgery. FFA were specifically developed to stimulate the growth of the mandible by positioning it forward into a Class I occlusion. Various kinds of FFA are employed to address Class II malocclusion in adults [2-6] The choice of FFA depends on the specific skeletal and dental abnormalities. The aim of the present review was to compare and assess the available evidence through a systematic review and meta-analysis, seeking to answer the following research question: Is there a difference in the treatment effects of FFA as compared to UclII malocclusion on skeleton-dental cephalometric measurements?

2. MATERIALS AND METHODS

Search Strategy: A systematic search swas carried out as per data mentioned in Table 1. The study included adolescents with Class II malocclusion undergoing treatment, irrespective of gender, ethnicity, or nationality. Evaluation involved lateral cephalograms to assess skeleton-dental markers, with the intervention being any

FFA Class II malocclusion. UclII malocclusion cases, matched by age and gender, served as the comparative group. The research aims for detailed outcomes through linear and angular dentoskeletal cephalometric analysis. Angular measurements included SNA, SNB, ANB, IMPA, SN-MP, SN-PP, MMA interincisal and gonial angle. Linear measurements included anterior cranial base (N-S), mandibular length (Go-Me), maxillary length (ANS to PNS), and lower anterior facial height (LAFH - ANS to Me). Eligible study designs encompassed clinical trials, in-vivo studies, randomized/controlled/non-randomized/quasi-experimental/non-experimental cohort studies, specifically comparing FFA effects in Class II malocclusion to UclII.
Exclusion of inaccessible studies, single-intervention studies, and non-clinically applicable types. Additionally, studies with only abstracts, lacking full-text availability, and cephalometric analyses in specific cases were disregarded. Exclusions cover impacted anterior teeth, prosthetic restorations, prior orthodontic treatment, orthognathic surgery, cleft lip/palate syndromes, skeletal malformations, systemic diseases, and drug therapy cases. Two reviewers systematically evaluated study titles and abstracts, eliminating duplicates and excluding irrelevant articles. They achieved high concordance levels (Cohen's kappa: 0.92 for titles/abstracts, 0.94 for full texts).

Data extraction

Two independent reviewers meticulously conducted the data extraction process, gathering information from included studies. Discrepancies were resolved through consensus after thorough discussion. For all studies, details on publication, participant demographics, settings, interventions, comparators, outcomes, design, analysis, results, funding sources, and conflicts of interest were accurately extracted and systematically recorded in Excel sheets.
The quality of RCT was evaluated using the Cochrane RoB-2 tool with RevMan software (Review Manager Version 5.3). Studies were categorized as having low, moderate, or high risk overall (Table 2 and 3). Non-randomized studies were assessed using the Methodological Index for Non-Randomized Studies (MINORS) tool (Table 4), which rates eight items on a scale from 0 (not reported) to 2 (reported and adequate), with a maximum score of 16 for non-comparative and 24 for comparative studies.

Sstatistical Analysis for Quantitative Synthesis

Continuous data mean and standard deviation were presented with 95% confidence intervals, setting significance at $P<0.05$. Heterogeneity was assessed through Chi-square, Tau-square, and I2 tests at $\alpha=0.10$. I2 represented real variability among studies' effect estimates, with significance at $P < 0.05$. Cochrane guidelines interpreted I2 values: 0-30% (not important), 30-60% (moderate), 50-90% (substantial), and 75-100% (considerable). Random Effects model (REM) was applied when I2 exceeded 50%. Subgroup analyses addressed clinical heterogeneity, and significance was set at a two-tailed p-value < 0.05. Funnel plots visually detected potential publication bias for studies with >10 counts, contributing to the meta-analysis's robustness.
Meta-analysis: Data synthesis was carried out using a descriptive synthesis, with a summary of the characteristics of each included study. For quantitative synthesis, a summary of the combined estimate related to the intervention effect was calculated as a mean of the differences of the effects of post-intervention in individual studies.[7]
Effect measures: Effect measures refer to statistical constructs that compare outcome data between two intervention groups. Examples include odds ratios (which compare the odds of an event between two groups) and mean differences (which compare mean values between two groups). For this study, mean difference (MD) was used as effect measures.[8]
Studies included in meta-analysis: Among the included studies, five studies provided result in form of mean and standard deviation and ten studies provided result in terms of mean difference and standard deviation. The values of mean as well as mean difference were used separately in quantitative analysis.
Also, in some studies two types of fixed functional appliances were used. These studies were considered separately for the different functional appliances used. (Table 5)

3. RESULTS

The screening process for section of articles is explained in the form of the PRISMA flowchart 2020 (Table 6) the Cochrane Handbook for systematic reviews of interventions, version 5.1.0. and 4th Edition of the JBI Reviewer's Manual and was registered at PROSPERO under registration code CRD4202343455655.
Sixteen studies[9-24] were included in the qualitative assessment. These studies were conducted in different parts of world 2 in each USA[9,19], Turkey[10,14], Germany[11,17], Brazil[12,20], Egypt[18,24] one in Syria[13], Canada[15], Spain[16], and Italy[23]. Among the included studies, three were randomized controlled trials[10,13,18] and thirteen were non-randomized clinical studies [9,11,12,14-17,22-24]. Different types of FFA were used in these studies such as MARA [9,19], Herbst[10,11,17,23], FLMGM[13], TFBC[12,14], Xbow[15], Austro Repositioner[16], MPA[20], Jasper jumper[20,22], FFRD[18,21,24], Twin Force[22], Splint FFRD[24]. A total of 984 participants were evaluated in this review with 571 participants in intervention group and 413 participants in control group.
Outcomes based on mean and standard deviation: In the evaluation of maxillary changes, three studies assessing SNA revealed a pooled value of -0.44[-0.78, -0.11], indicating a statistically significant

(p=0.008) reduction in SNA values with FFA compared UclII, with 0% heterogeneity, involving 74 participants in the intervention group and 72 in the control group. For Co-A, two studies demonstrated a pooled a non-significant (p=0.66) value of -0.34[-1.85, 1.17] for Co-A values with FFA, with 91% heterogeneity. (Table 7)
Three studies assessing mandibular changes reported a comssbined SNB value of -0.10[-0.43, 0.223], suggesting higher SNB with FFA versus no treatment, though not statistically significant (p=0.56) and 0% heterogeneity. For intermaxillary changes, three studies on ANB revealed a pooled value of -0.55[-1.06, -0.05], showing decreased ANB with FFA, significantly (p=0.03) with 55% heterogeneity among 74 and 70 participants in intervention and control groups, respectively. In dentoalveolar changes, three studies indicated a combined overjet reduction of -1.29[-1.63, -0.96]mm with FFA (Table 8).
Overall results were statistically significant (p<0.00001) with 0% heterogeneity, prompting the use of a REM due to high heterogeneity. However, for overbite and molar relationship, pooled values of -0.93[-2.92, 1.07] and -1.73[-4.28, 0.82]mm respectively were not statistically significant (p=0.36, p=0.18), both with high heterogeneity, leading to the application of a REM (Table 9 And 10).
In assessing mandibular changes, three studies examined SNB, revealing a pooled value of -0.10[-0.43, 0.223], suggesting greater SNB values with functional appliances compared to no treatment.

Outcomes based on mean difference and standard deviation: In examining maxillary changes, eight studies on SNA showed a pooled value of -0.66[-0.94, -0.38], indicating a reduced SNA difference post-treatment with functional appliances, significantly so (p<0.00001) with 48% heterogeneity, necessitating a REM due to this high heterogeneity. Regarding Co-A, five studies yielded a pooled value of -0.14[-0.67, 0.38]mm, suggesting a minor decrease post-treatment, though not significant (p=0.59 with 81% heterogeneity, also leading to the use of a REM. (Table 11)
In mandibular evaluations, eight studies on SNB revealed a pooled value of 0.38[0.03, 0.73], showing a significant increase in SNB post-treatment with functional appliances (p=0.03), amid 69% heterogeneity, prompting a REM usage. Six studies on Co-Gn reported a pooled value of 0.54[0.13, 0.95]mm, indicating a notable increase in Co-Gn post-treatment, significantly so (p=0.01) with 71% heterogeneity. Three studies on Go-Gn showed a pooled value of 0.53[0.07, 0.98]mm, suggesting a smaller increase in Go-Gn, not significant with 32% heterogeneity. Two studies on FMPA angle yielded a pooled value of -0.18[-0.69, 0.33], indicating a minor decrease in FMPA post-treatment, not significant (p=0.49) with 60% heterogeneity. High heterogeneity in these cases necessitated REM. (Table 12)
In a thorough exploration of intermaxillary and dentoalveolar landmarks (Table 13 and 14), several studies examined the impact of FFA compared to UclII. Six studies on the ANB angle reported a notable decrease (-0.95[-1.79, -0.11], p=0.03) with substantial 90% heterogeneity. Similarly, Witts's appraisal, from three studies, demonstrated a significant decrease (-1.92[-2.51, -1.32]) with 50% heterogeneity. The ANS-Me measurement, across three studies, showed a non-significant increase (0.75[-0.15, 1.64]mm) with 80% heterogeneity. In dentoalveolar landmarks, the IMPA angle, evaluated in three studies, revealed a significant increase (0.62[0.31, 0.93]) with no heterogeneity. The Go Gn SN angle, from two studies, indicated an increased, yet non-significant change (0.21[-0.09, 0.51]) with no heterogeneity. The nasolabial angle, across two studies, exhibited a significant decrease (0.61[0.18, 1.05]) with 38% heterogeneity. Overjet, analyzed in seven studies, displayed a significant reduction (-2.08[-2.62, -1.54]mm) with 75% heterogeneity, while overbite, from five studies, demonstrated a significant decrease (-1.08[-1.79, -0.37]mm) with 85% heterogeneity. Lastly, the molar relationship, assessed in two studies, indicated a non-significant reduction (-2.04[-5.25, 1.17]mm) with a high 98% heterogeneity. The REM was frequently applied due to the observed high heterogeneity. This thorough analysis highlights the nuanced impact of functional appliances on various skeleton-dental parameters, stressing the need to consider individual variability and the degree of heterogeneity in orthodontic treatment outcomes. A summary of the characteristics of the studies included to derive the above results has been given in Table 15.

4. DISCUSSION

The current systematic review and meta-analysis assesses if there is a difference in the treatment effects of FFA as compared to UClII patients on dental and skeletal cephalometric measurement. All articles published from 01/01/2000 until 31/07/2023 were searched and were included in the present study. Studies that evaluated MARA, FFRD, Jasper Jumper, Herbst, FLMGM, TFBC, Xbow, Austro Repositioner, MPA, Twin Force, Splint FFRD were included.
The review of studies focusing on orthodontic appliances for the treatment of Class II malocclusion provides a comprehensive understanding of their effectiveness and outcomes. Alhammadi[18] in his study comparing twin block and FFRD revealed twin block showed greater maxillary retrusive effect than FFRD. Twin block appliance also had greater mandibular growth advancing potential than FFRD. However, neither of the appliances seemed to have an effect on maxillary anterior position(A) or vertical growth of condyle (Co). Elkordy[24] advocated restricting maxillary growth by the Splint FFRD were significant due to noticeable reduction in SNA. Guimarães [12] concluded that the Twin Force Bite Corrector has a significant restricting effect on the growth of maxillary complex when compared to the controls. Thus, an overall restrictive effect

on maxilla could be concluded by a pooled decreased in SNA by these fixed functional appliances. Dentoalveolar landmarks when assessed, a significant pooled reduction in overjet could be obtained from studies carried out by Ardeshna[19], Bock[11] and Guimarães[12]. MARA appliance, investigated by Al-Jewair[9] in 2013, showcased its efficacy in a retrospective study and he concluded that the appliance significantly normalized Class II malocclusion through notable skeletal and dentoalveolar changes. Numerous studies have been conducted on the Herbst appliance, examined in studies by Baysal[10] (2013) who concluded that when compared with twin block greater incisor inclination was seen with mandibular anterior teeth but the functional appliance was more effective in treating skeletal discrepancy than Herbst appliance. Bock[11] (2013) conducted long term studies on the stability of the effects of the Herbst appliance which stated that the results were stable the long term and only minor changes in overbite, overjet were seen that were not clinically significant. Henriques's[20] (2019) research encompassed randomized controlled trials (RCTs) and retrospective studies on the Jasper Jumper and MPA and demonstrated improvements in skeletal and dentoalveolar aspects, The JJ group presented a greater restriction of growth and anterior displacement of the maxilla and greater maxillary retrusion and the MPA group showed a significantly greater increase of mandibular effective length. Fontes[22] in his study between the JJ and the Twin Force concluded that Twin Force seems to provide more skeletal effects than the Jasper Jumper, since it demonstrated greater maxillary growth restriction and mandibular length increase.

Comparative studies on orthodontic appliances for Class II malocclusion highlight varying effects on skeletal and dentoalveolar structures. SNA was significantly reduced in studies conducted by Dalci[12], Elkordy[24] and Henriques[20] who advocated the Twin Force bite Corrector, FFRD, MPA and Jasper Jumper respectively. The mandibular parameters such as SNB, CO-GN, Go-GN, FMPA did not show statistically significant changes when the functional appliances were compared with their controls.

The majority of these appliances prove effective in correcting Class II malocclusion, but through diverse mechanisms. The differential effects of these appliances on incisor positioning and skeletal changes highlight the nuanced nature of orthodontic treatments. Selecting the right appliance, tailored to the specific malocclusion and desired outcomes, is crucial for effective treatment. Long-term stability and treatment outcomes also vary across different appliances. Some show remarkable stability, maintaining outcomes similar to untreated Class I cases. Patient-specific responses, influenced by individual growth patterns and maturational age, necessitate tailored treatment plans. Appliances differ in their emphasis on skeletal, dental, and soft-tissue changes, guiding clinicians in selecting the most appropriate device based on treatment objectives.

Limitations: High heterogeneity among studies made it difficult to synthesize and pool data effectively. By not including soft tissue parameters, the review might miss critical aspects relevant to the effectiveness of FFA. The included studies vary widely in terms of populations, interventions, and outcomes thus interpreting the overall findings may become complex. The combined effect of these limitations can lead to reduced external validity.

5. CONCLUSION

- Comparative observations emphasized variations among appliances, underlining the intricacy of Class II malocclusion treatment.
- The systematic review and meta-analysis addressed existing literature gaps, revealing the efficacy of appliances like MARA, Herbst, and Twin Block in inducing significant skeletal and dentoalveolar changes.
- Despite diverse mechanisms, most appliances proved effective, highlighting the importance of personalized treatment plans that account for skeletal, dental, and soft-tissue changes.
- The analysis of differential effects emphasized the need for appliance selection based on malocclusion characteristics, and insights into long-term stability and facial profile impacts underscored the nuanced nature of these effects.
- This discussion stresses the vital role of treatment personalization in guiding orthodontic practitioners toward delivering effective, patient-centric care for Class II malocclusion individuals.

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TABLES

Table 1: The search strategy and PICOS tool

Search strategy	
Focused Question	Is there a difference in the treatment effects of FFAas compared to untreated patients with Class II malocclusion on dental and skeletal cephalometric measurements?
Search strategy	
Population	((("Class II malocclusion"[All Fields] OR "malocclusion "[All Fields] OR " Malocclusion, Angle Class II "[MeSH Terms] OR " Malocclusion, Angle Class II "[All Fields] OR " Angle Class II "[All Fields] OR " Class II, Angle "[All Fields] OR "Class II division 1 malocclusions" [All Fields])))
Intervention (#1)	"Orthodontic Appliances, Functional"[All Fields] OR "fixed lingual mandibular growth modificator"[All Fields] OR "Herbst appliance"[All Fields] OR "mandibular anterior repositioning appliance"[All Fields] OR "functional mandibular advancer"[All Fields] OR "Forsus Device"[All Fields] OR "AdvanSync"[All Fields] OR "Functional Orthodontic Appliances"[All Fields] OR "Jasper Jumper"[All Fields])) OR (("Twin force Bite corrector"[All Fields]))
Comparisons (#2)	("Untreated"[All Fields] OR "Untreated Class II Malocclusion"[All Fields] OR "Control group"[All Fields]))
Outcomes (#3)	("Angular measurements" [Text Word] OR "Linear measurements" [Text Word] OR Dental [Text Word] OR Skeletal [Text Word] OR Cephalometric Analysis [Text Word]))
Study design (#4)	(Clinical trials [MeSH] OR randomized controlled studies [Text Word] OR randomized control trials [MeSH] OR randomized control clinical trial MeSH OR non-randomized control trials [Text Word] OR Quasi experimental studies [Text Word] OR before and after study design [Text Word] OR cohort studies [Text Word] OR in vivo study [Text Word]) OR cross-sectional studies [Text Word] OR comparative studies[Text Word] OR observational studies [Text Word]))
Search Combination	#1 AND #2 AND #3 AND #4
Database search	
Language	Articles in English language
Electronic Databases	PubMed/MEDLINE, Cochrane Central Register of Controlled Trials, Scopus, DOAJ
Period of Publication	Studies published between 1-1-2013 to 31-07-2023

zTable 2: Risk of bias graph

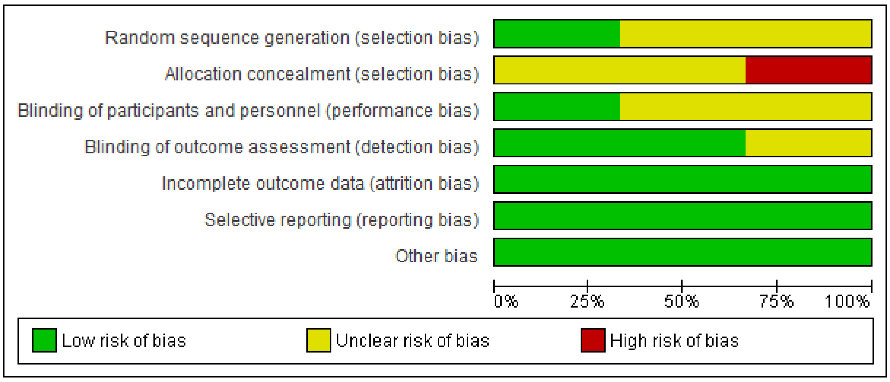

Table 3: Risk of bias summary

Table 4: Quality assessment according to MINORS tool

Study Id	A clearly stated aim	Inclusion of consecutive patients	Prospective collection of data	End points appropriate to the aim of the study	Unbiased assessment of the study endpoint	Follow-up period appropriate to the aim of the study	Loss to follow up less than 5%	Prospective calculation of the study size	***An adequate control group**	***Contemporary groups**	***Baseline equivalence of groups**	***Adequate statistical analyses**	Total
Al-Jewair 2013 [9]	2	2	0	1	2	2	2	0	2	2	2	2	19
Bock 2013 [11]	2	2	0	1	2	2	2	0	2	2	2	2	19
Guimaraes 2013 [12]	2	2	0	1	2	2	2	2	2	2	2	2	21
Dalci 2014 [14]	2	2	0	1	2	2	2	2	2	2	2	2	21
Ehsani 2015 [15]	1	2	0	1	2	2	2	2	2	2	2	2	20
Austro 2018 [16]	2	2	2	2	2	2	2	2	2	2	2	2	24

Bock 2018 [17]	2	2	0	1	2	2	2	0	2	2	2	2	19
Ardeshna 2019 [19]	2	2	0	1	2	2	2	0	2	2	2	2	19
Henriques 2019 [20]	2	1	0	2	2	2	2	2	2	2	2	2	21
Alhoraibi 2020 [21]	2	2	0	2	2	2	2	0	2	2	2	2	20
Fontes 2020 [22]	2	2	0	2	2	2	2	2	2	2	2	2	22
Giuca 2020 [25]	2	2	0	2	2	2	2	2	2	2	2	2	22
Elkordy 2021 [24]	1	2	0	2	2	2	2	2	2	2	2	2	21

Table 5: Studies considered separately for the different functional appliances used

Study ID	**Functional appliance used**
Baysal 2013 (A)	Herbst appliance
Baysal 2013 (B)	Twin Block
Ehsani 2015 (A)	Twin Block
Ehsani 2015 (B)	Xbow
Dalci 2014 (A)	TFBC
Dalci 2014 (B)	Activator
Alhammadi 2019 (A)	Twin block
Alhammadi 2019 (B)	FFRD
Henriques 2019 (A)	MPA
Henriques 2019 (B)	Jasper
Fontes 2020 (A)	Jasper Jumper
Fontes 2020 (B)	Twin Force
Elkordy 2021 (A)	FFRD
Elkordy 2021 (B)	Splint FFRD

Table 6: PRISMA flow diagram

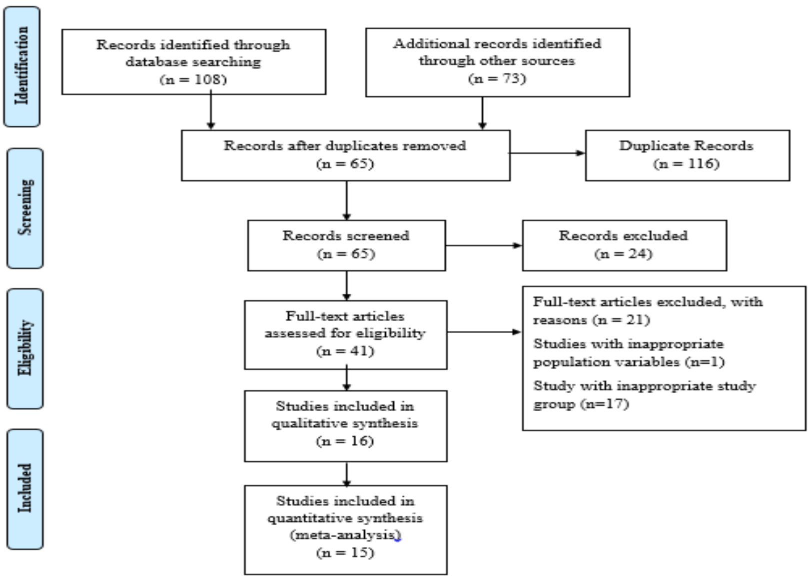

Table 7: Forest plot for Maxilla landmarks

Study or Subgroup	Functional appliance Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
2.1.1 SNA								
Alhammadi 2019	79.1	2.71	21	81.31	2.74	20	26.8%	-0.80 [-1.43, -0.16]
Elkordy 2021 (A)	83.01	2.23	15	83.36	3.12	16	22.0%	-0.13 [-0.83, 0.58]
Elkordy 2021 (B)	81.74	1.87	15	83.36	3.12	16	20.9%	-0.61 [-1.33, 0.11]
Guimaraes 2013	81.54	4.28	23	82.59	3.84	20	30.2%	-0.25 [-0.85, 0.35]
Subtotal (95% CI)			**74**			**72**	**100.0%**	**-0.44 [-0.78, -0.11]**
Heterogeneity: Tau² = 0.00; Chi² = 2.54, df = 3 (P = 0.47); I² = 0%								
Test for overall effect: Z = 2.63 (P = 0.008)								
2.1.2 Co-A								
Alhammadi 2019	84	4.95	21	81.99	4	18	50.1%	0.43 [-0.20, 1.07]
Guimaraes 2013	84.58	4.99	23	89.63	3.8	20	49.9%	-1.11 [-1.75, -0.46]
Subtotal (95% CI)			**44**			**38**	**100.0%**	**-0.34 [-1.85, 1.17]**
Heterogeneity: Tau² = 1.08; Chi² = 11.04, df = 1 (P = 0.0009); I² = 91%								
Test for overall effect: Z = 0.44 (P = 0.66)								
Test for subgroup differences: Chi² = 0.02, df = 1 (P = 0.89), I² = 0%								

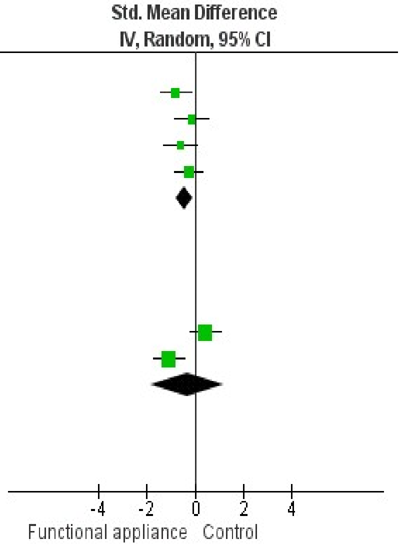

Table 8: Forest plot for Mandible landmarks

Study or Subgroup	Functional appliance Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.1.1 SNB								
Alhammadi 2019	72.48	3.4	21	73.85	2.15	18	26.6%	-0.46 [-1.10, 0.18]
Elkordy 2021 (A)	75.99	2.29	15	75.46	2.63	16	21.7%	0.21 [-0.50, 0.92]
Elkordy 2021 (B)	75.95	1.22	15	75.46	2.63	16	21.7%	0.23 [-0.48, 0.94]
Guimaraes 2013	77.2	3.54	23	78.11	4.24	20	30.0%	-0.23 [-0.83, 0.37]
Subtotal (95% CI)			**74**			**70**	**100.0%**	**-0.10 [-0.43, 0.23]**
Heterogeneity: Tau² = 0.00; Chi² = 3.00, df = 3 (P = 0.39); I² = 0%								
Test for overall effect: Z = 0.58 (P = 0.56)								
Total (95% CI)			**74**			**70**	**100.0%**	**-0.10 [-0.43, 0.23]**
Heterogeneity: Tau² = 0.00; Chi² = 3.00, df = 3 (P = 0.39); I² = 0%								
Test for overall effect: Z = 0.58 (P = 0.56)								
Test for subgroup differences: Not applicable								

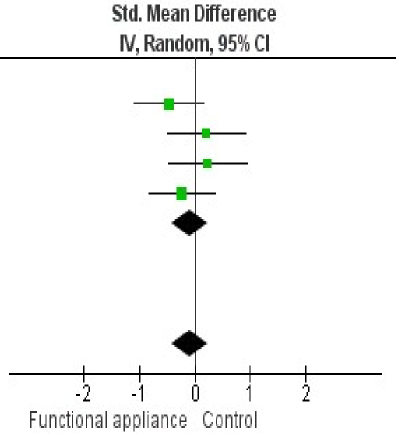

Table 9: Forest plot for Inetermaxillary landmarks

Study or Subgroup	Functional appliance Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
3.1.1 ANB								
Alhammadi 2019	6.72	1.75	21	7.53	1.52	18	26.5%	-0.48 [-1.12, 0.16]
Elkordy 2021 (A)	7.02	1.53	15	7.66	1.23	16	24.0%	-0.45 [-1.17, 0.26]
Elkordy 2021 (B)	5.66	1.6	15	7.66	1.23	16	21.6%	-1.37 [-2.16, -0.58]
Guimaraes 2013	4.35	2.31	23	4.49	1.31	20	27.9%	-0.07 [-0.67, 0.53]
Subtotal (95% CI)			**74**			**70**	**100.0%**	**-0.55 [-1.06, -0.05]**
Heterogeneity: Tau² = 0.14; Chi² = 6.61, df = 3 (P = 0.09); I² = 55%								
Test for overall effect: Z = 2.14 (P = 0.03)								
Total (95% CI)			**74**			**70**	**100.0%**	**-0.55 [-1.06, -0.05]**
Heterogeneity: Tau² = 0.14; Chi² = 6.61, df = 3 (P = 0.09); I² = 55%								
Test for overall effect: Z = 2.14 (P = 0.03)								
Test for subgroup differences: Not applicable								

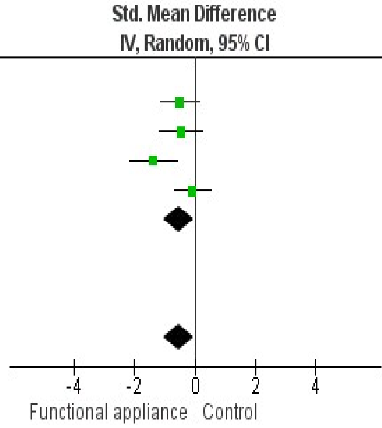

Table 10: Forest plot for Dentoalveolar landmarks

Study or Subgroup	Functional appliance Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
4.1.2 Overjet								
Ardeshna 2019	2.93	1.34	24	5	1.28	13	19.0%	-1.53 [-2.30, -0.76]
Bock 2018	2.2	0.85	20	3.2	0.81	31	30.1%	-1.19 [-1.80, -0.58]
Guimaraes 2013	2.88	1.58	233	4.89	1.75	20	50.9%	-1.26 [-1.73, -0.79]
Subtotal (95% CI)			**277**			**64**	**100.0%**	**-1.29 [-1.63, -0.96]**
Heterogeneity: Tau² = 0.00; Chi² = 0.50, df = 2 (P = 0.78); I² = 0%								
Test for overall effect: Z = 7.54 (P < 0.00001)								
4.1.3 Overbite								
Bock 2018	2.5	1.49	20	2.4	1.21	31	50.7%	0.07 [-0.49, 0.64]
Guimaraes 2013	1.02	1.64	23	4.41	1.76	20	49.3%	-1.96 [-2.70, -1.22]
Subtotal (95% CI)			**43**			**51**	**100.0%**	**-0.93 [-2.92, 1.07]**
Heterogeneity: Tau² = 1.96; Chi² = 18.41, df = 1 (P < 0.0001); I² = 95%								
Test for overall effect: Z = 0.91 (P = 0.36)								
4.1.4 Molar relationship								
Ardeshna 2019	-5.57	1.31	24	0.35	1.09	13	31.9%	-4.67 [-5.99, -3.36]
Bock 2018	0	0.15	20	-0.1	0.12	31	34.2%	0.74 [0.16, 1.33]
Guimaraes 2013	-1.5	1.34	23	0.5	1.36	20	34.0%	-1.45 [-2.14, -0.77]
Subtotal (95% CI)			**67**			**64**	**100.0%**	**-1.73 [-4.28, 0.82]**
Heterogeneity: Tau² = 4.88; Chi² = 63.47, df = 2 (P < 0.00001); I² = 97%								
Test for overall effect: Z = 1.33 (P = 0.18)								

Test for subgroup differences: Chi² = 0.24, df = 2 (P = 0.89), I² = 0%

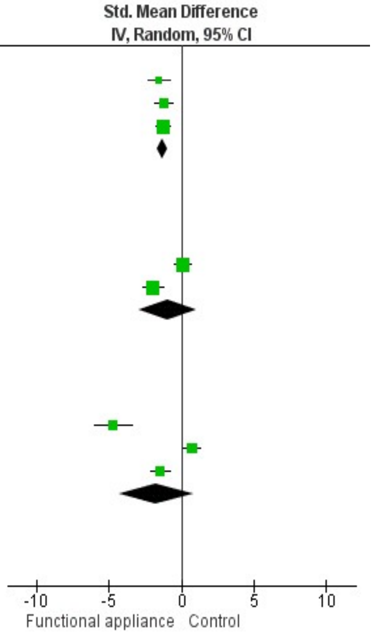

Table 11: Forest plot for Maxilla landmarks

Study or Subgroup	Functional appliance Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
5.1.1 SNA								
Al-Jewari 2013	-0.5	1.5	40	0.4	1.7	24	11.7%	-0.56 [-1.08, -0.05]
Alali 2014	-0.4	0.7	21	0.2	0.8	11	8.0%	-0.80 [-1.55, -0.04]
Alhammadi 2019	-0.26	0.83	21	-0.07	0.51	18	9.8%	-0.27 [-0.90, 0.37]
Dalci 2014	-0.36	0.37	10	0.52	0.24	10	3.8%	-2.70 [-3.98, -1.42]
Elkordy 2021 (A)	-0.05	0.85	15	0.3	0.88	16	8.6%	-0.39 [-1.11, 0.32]
Elkordy 2021 (B)	-0.8	0.51	15	0.3	0.88	16	7.4%	-1.48 [-2.28, -0.67]
Fontes 2020 (A)	-0.2	2.37	20	0.74	2.1	20	9.9%	-0.41 [-1.04, 0.22]
Fontes 2020 (B)	-0.27	2.02	20	0.74	2.1	20	9.8%	-0.48 [-1.11, 0.15]
Guimaraes 2013	-0.26	5.11	23	0.85	2.58	20	10.3%	-0.26 [-0.87, 0.34]
Henriques 2019 (A)	-0.83	3.35	24	0.73	2.59	22	10.5%	-0.51 [-1.10, 0.08]
Henriques 2019 (B)	-1.42	2.31	25	0.73	2.59	22	10.3%	-0.86 [-1.47, -0.26]
Subtotal (95% CI)			**234**			**199**	**100.0%**	**-0.66 [-0.94, -0.38]**
Heterogeneity: Tau² = 0.10; Chi² = 19.06, df = 10 (P = 0.04); I² = 48%								
Test for overall effect: Z = 4.64 (P < 0.00001)								
5.1.2 Co-A								
Al-Jewari 2013	1.8	0.6	40	1.6	0.7	24	15.2%	0.31 [-0.20, 0.82]
Alhammadi 2019	1.4	0.11	21	1.1	0.31	18	13.5%	1.31 [0.61, 2.00]
Fontes 2020 (A)	0.66	2.39	20	1.82	1.07	20	14.1%	-0.61 [-1.25, 0.02]
Fontes 2020 (B)	0.75	3.38	20	1.82	1.07	20	14.1%	-0.42 [-1.05, 0.21]
Guimaraes 2013	-0.26	6.27	23	2.4	3.05	20	14.3%	-0.52 [-1.13, 0.09]
Henriques 2019 (A)	2.81	2.13	24	2.95	2.59	22	14.6%	-0.06 [-0.64, 0.52]
Henriques 2019 (B)	0.58	2.2	25	2.95	2.59	22	14.3%	-0.98 [-1.58, -0.37]
Subtotal (95% CI)			**173**			**146**	**100.0%**	**-0.14 [-0.67, 0.38]**
Heterogeneity: Tau² = 0.40; Chi² = 31.04, df = 6 (P < 0.0001); I² = 81%								
Test for overall effect: Z = 0.55 (P = 0.59)								

Test for subgroup differences: Chi² = 2.92, df = 1 (P = 0.09), I² = 65.7%

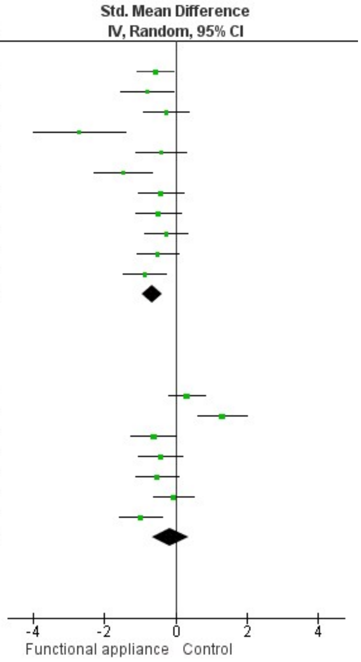

Table 12: Forest plot for Mandible landmarks

Study or Subgroup	Functional appliance Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
5.2.1 SNB								
Al-Jewari 2013	1.5	1.6	40	0.2	0.9	24	10.2%	0.93 [0.40, 1.46]
Alali 2014	1.7	1.1	21	-0.2	0.7	17	7.9%	1.97 [1.18, 2.76]
Alhammadi 2019	-0.29	0.93	21	0.05	0.56	18	9.3%	-0.43 [-1.06, 0.21]
Dalci 2014	0.93	0.49	10	0.799	0.46	10	7.2%	0.26 [-0.62, 1.15]
Elkordy 2021 (A)	0.22	0.66	15	-0.07	1.05	16	8.6%	0.32 [-0.39, 1.03]
Elkordy 2021 (B)	0.35	0.35	15	-0.07	1.05	16	8.6%	0.52 [-0.20, 1.23]
Fontes 2020 (A)	0.74	1.59	20	0.46	2.09	20	9.4%	0.15 [-0.47, 0.77]
Fontes 2020 (B)	1.39	1.94	20	0.46	2.09	20	9.4%	0.45 [-0.18, 1.08]
Guimaraes 2013	1.5	4.2	23	0.7	2.15	20	9.6%	0.23 [-0.37, 0.83]
Henriques 2019 (A)	1.04	2.61	24	0.48	2.19	22	9.8%	0.23 [-0.35, 0.81]
Henriques 2019 (B)	0.02	1.07	25	0.48	2.19	22	9.8%	-0.27 [-0.84, 0.31]
Subtotal (95% CI)			**234**			**205**	**100.0%**	**0.38 [0.03, 0.73]**
Heterogeneity: Tau² = 0.24; Chi² = 31.82, df = 10 (P = 0.0004); I² = 69%								
Test for overall effect: Z = 2.12 (P = 0.03)								
5.2.2 Co-Gn (mm)								
Al-Jewari 2013	4.5	3.6	40	2.6	2	24	13.9%	0.60 [0.09, 1.12]
Alali 2014	3.5	1.4	21	1.2	1.1	17	11.0%	1.77 [1.00, 2.53]
Baysal 2013	3	2.63	20	3.83	2.62	11	11.3%	-0.31 [-1.05, 0.43]
Fontes 2020 (A)	4.18	2.15	20	2.94	1.75	20	12.5%	0.62 [-0.02, 1.26]
Fontes 2020 (B)	6.23	4.64	20	2.94	1.75	20	12.3%	0.92 [0.26, 1.57]
Guimaraes 2013	4.08	6.96	23	4.37	4.59	20	12.9%	-0.05 [-0.65, 0.55]
Henriques 2019 (A)	7.14	3.57	24	4.11	3.55	22	12.9%	0.84 [0.23, 1.44]
Henriques 2019 (B)	4.17	2.91	25	4.11	3.55	22	13.2%	0.02 [-0.55, 0.59]
Subtotal (95% CI)			**193**			**156**	**100.0%**	**0.54 [0.13, 0.95]**
Heterogeneity: Tau² = 0.25; Chi² = 24.06, df = 7 (P = 0.001); I² = 71%								
Test for overall effect: Z = 2.56 (P = 0.01)								
5.2.3 Go-Gn (mm)								
Al-Jewari 2013	3.3	2.5	40	1.6	1.1	24	43.7%	0.80 [0.28, 1.33]
Baysal 2013	3	2.63	20	2.75	2.08	20	35.7%	0.10 [-0.52, 0.72]
Dalci 2014	1.84	0.84	10	1.41	0.22	10	20.5%	0.67 [-0.24, 1.58]
Subtotal (95% CI)			**70**			**54**	**100.0%**	**0.53 [0.07, 0.98]**
Heterogeneity: Tau² = 0.05; Chi² = 2.94, df = 2 (P = 0.23); I² = 32%								
Test for overall effect: Z = 2.24 (P = 0.02)								
5.2.4 FMPA								
Al-Jewari 2013	0.6	2.7	40	1.8	1.5	24	35.5%	-0.51 [-1.02, 0.01]
Henriques 2019 (A)	-0.73	2.2	24	-0.02	1.91	22	32.1%	-0.34 [-0.92, 0.25]
Henriques 2019 (B)	0.78	2.62	25	-0.02	1.91	22	32.4%	0.34 [-0.24, 0.92]
Subtotal (95% CI)			**89**			**68**	**100.0%**	**-0.18 [-0.69, 0.33]**
Heterogeneity: Tau² = 0.12; Chi² = 4.96, df = 2 (P = 0.08); I² = 60%								
Test for overall effect: Z = 0.69 (P = 0.49)								

Test for subgroup differences: Chi² = 5.57, df = 3 (P = 0.13), I² = 46.2%

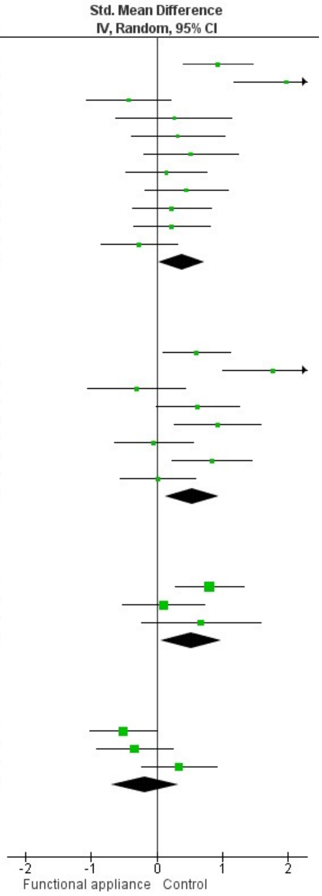

Table 13: Forest plot for Intermaxillary landmarks

Study or Subgroup	Functional appliance Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
5.3.1 ANB								
Alali 2014	-2	0.9	21	0.4	0.7	40	10.5%	-2.40 [-2.84, -1.96]
Alhammadi 2019 (A)	-2.49	0.74	23	0.29	0.48	18	10.6%	-2.78 [-3.16, -2.40]
Alhammadi 2019 (B)	-0.03	0.79	21	0.29	0.48	18	10.5%	-0.32 [-0.72, 0.08]
Dalci 2014 (A)	-1.29	0.49	10	-0.27	0.27	10	10.6%	-1.02 [-1.37, -0.67]
Dalci 2014 (B)	-1.14	0.48	10	-0.27	0.27	10	10.6%	-0.87 [-1.21, -0.53]
Elkordy 2021 (A)	-0.28	0.53	15	0.06	0.8	15	10.4%	-0.34 [-0.83, 0.15]
Elkordy 2021 (B)	1.36	0.87	15	0.06	0.8	15	10.2%	1.30 [0.70, 1.90]
Fontes 2020 (A)	-0.95	1.88	20	0.27	1.2	20	9.1%	-1.22 [-2.20, -0.24]
Fontes 2020 (B)	-1.54	1.59	20	0.27	1.2	20	9.4%	-1.81 [-2.68, -0.94]
Guimaraes 2013	-1.74	3.07	23	0.17	1.1	20	8.0%	-1.91 [-3.25, -0.57]
Subtotal (95% CI)			**178**			**186**	**100.0%**	**-1.12 [-1.85, -0.38]**
Heterogeneity: Tau² = 1.29; Chi² = 201.21, df = 9 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 2.99 (P = 0.003)								
5.3.2 Witts								
Dalci 2014 (A)	-2.94	0.53	10	-1.1	0.58	10	23.1%	-1.84 [-2.33, -1.35]
Dalci 2014 (B)	-1.95	0.83	10	-1.1	0.58	10	22.7%	-0.85 [-1.48, -0.22]
Fontes 2020 (A)	-3.48	2.32	20	1.17	2.05	20	19.6%	-4.65 [-6.01, -3.29]
Fontes 2020 (B)	-3.32	2.77	20	1.17	2.05	20	18.8%	-4.49 [-6.00, -2.98]
Guimaraes 2013	-3.99	4.75	23	1.08	1.96	20	15.7%	-5.07 [-7.19, -2.95]
Subtotal (95% CI)			**83**			**80**	**100.0%**	**-3.17 [-4.61, -1.73]**
Heterogeneity: Tau² = 2.28; Chi² = 46.37, df = 4 (P < 0.00001); I² = 91%								
Test for overall effect: Z = 4.31 (P < 0.0001)								
5.3.3 ANS-Me (mm)								
Al-Jewari 2013	0	8	40	0.1	2.3	24	11.5%	-0.10 [-2.74, 2.54]
Baysal 2013 (A)	4.35	2.27	20	2.05	1.73	20	20.2%	2.30 [1.05, 3.55]
Baysal 2013 (B)	3.85	2.17	20	2.05	1.73	20	20.5%	1.80 [0.58, 3.02]
Dalci 2014 (A)	1.81	1.05	10	0.59	0.7	10	23.3%	1.22 [0.44, 2.00]
Dalci 2014 (B)	4.08	0.61	10	0.59	0.7	10	24.4%	3.49 [2.91, 4.07]
Subtotal (95% CI)			**100**			**84**	**100.0%**	**1.96 [0.75, 3.17]**
Heterogeneity: Tau² = 1.47; Chi² = 26.74, df = 4 (P < 0.0001); I² = 85%								
Test for overall effect: Z = 3.18 (P = 0.001)								

Test for subgroup differences: Chi² = 31.19, df = 2 (P < 0.00001), I² = 93.6%

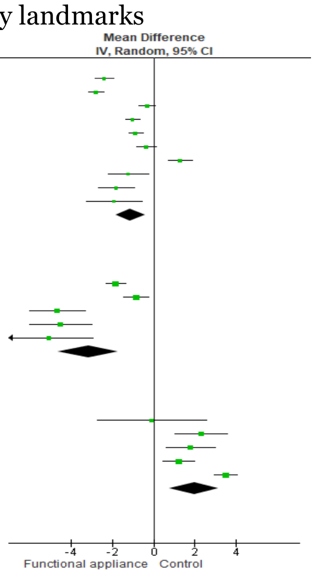

Table 14: Forest plot for Dentoalveolar landmarks

Study or Subgroup	Functional appliance Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
5.4.1 IMPA								
Ardeshna 2019	4.9	9.51	24	0.84	2.24	13	20.7%	0.51 [-0.18, 1.19]
Guimaraes 2013	4.53	8.49	23	-0.07	3.6	20	25.5%	0.68 [0.06, 1.29]
Henriques 2019 (A)	4.57	9.02	24	-0.1	1.4	22	27.2%	0.70 [0.10, 1.29]
Henriques 2019 (B)	2.43	5.95	22	-0.1	1.4	22	26.6%	0.57 [-0.03, 1.18]
Subtotal (95% CI)			**93**			**77**	**100.0%**	**0.62 [0.31, 0.93]**
Heterogeneity: Tau² = 0.00; Chi² = 0.22, df = 3 (P = 0.97); I² = 0%								
Test for overall effect: Z = 3.90 (P < 0.0001)								
5.4.2 Go Gn SN angle								
Fontes 2020 (A)	0.05	2.27	20	-0.63	2.8	20	23.2%	0.26 [-0.36, 0.88]
Fontes 2020 (B)	0.11	3.24	20	-0.63	2.8	20	23.3%	0.24 [-0.38, 0.86]
Henriques 2019 (A)	-0.56	3.06	24	-0.28	2.3	22	26.9%	-0.10 [-0.68, 0.48]
Henriques 2019 (B)	0.7	1.83	25	-0.28	2.3	22	26.6%	0.47 [-0.11, 1.05]
Subtotal (95% CI)			**89**			**84**	**100.0%**	**0.21 [-0.09, 0.51]**
Heterogeneity: Tau² = 0.00; Chi² = 1.89, df = 3 (P = 0.59); I² = 0%								
Test for overall effect: Z = 1.40 (P = 0.16)								
5.4.3 Nasolabial angle								
Elkordy 2021 (A)	2.48	6.79	15	-2.95	4.08	16	22.3%	0.95 [0.20, 1.70]
Elkordy 2021 (B)	2.21	4.78	15	-2.95	4.08	16	21.6%	1.13 [0.37, 1.90]
Fontes 2020 (A)	1.67	8.69	20	-1.08	9.02	20	28.0%	0.30 [-0.32, 0.93]
Fontes 2020 (B)	0.92	6.66	20	-1.08	9.02	20	28.1%	0.25 [-0.38, 0.87]
Subtotal (95% CI)			**70**			**72**	**100.0%**	**0.61 [0.18, 1.05]**
Heterogeneity: Tau² = 0.07; Chi² = 4.80, df = 3 (P = 0.19); I² = 38%								
Test for overall effect: Z = 2.77 (P = 0.006)								
5.4.4 Overjet								
Alali 2014	-3.3	2.9	21	0.7	0.9	40	12.6%	-2.15 [-2.80, -1.49]
Ardeshna 2019	-4.72	2.26	24	-0.18	0.52	13	10.9%	-2.39 [-3.28, -1.50]
Baysal 2013	-0.58	2.73	20	0.38	1.31	11	12.0%	-0.40 [-1.14, 0.34]
Dalci 2014	-4.69	1.22	10	-0.15	0.27	10	5.3%	-4.92 [-6.84, -3.01]
Fontes 2020 (A)	-4.05	2.29	20	0.05	1.12	20	11.5%	-2.23 [-3.03, -1.42]
Fontes 2020 (B)	-3.8	2.12	20	0.05	1.12	20	11.5%	-2.23 [-3.03, -1.42]
Guimaraes 2013	-3.83	3.02	23	0.18	1.28	20	12.3%	-1.66 [-2.36, -0.95]
Henriques 2019 (A)	-5.64	2.54	24	-0.08	1.39	22	11.5%	-2.64 [-3.44, -1.83]
Henriques 2019 (B)	-3.7	2.38	25	-0.08	1.39	22	12.4%	-1.80 [-2.48, -1.11]
Subtotal (95% CI)			**187**			**178**	**100.0%**	**-2.08 [-2.62, -1.54]**
Heterogeneity: Tau² = 0.49; Chi² = 31.81, df = 8 (P = 0.0001); I² = 75%								
Test for overall effect: Z = 7.55 (P < 0.00001)								
5.4.5 Overbite								
Baysal 2013	2	1.82	20	0.05	1.3	11	14.1%	1.14 [0.35, 1.94]
Dalci 2014	-2.69	1.02	10	-0.46	0.44	10	11.0%	-2.72 [-4.00, -1.43]
Fontes 2020 (A)	-2.52	1.46	20	-0.63	1.35	20	14.8%	-1.32 [-2.01, -0.63]
Fontes 2020 (B)	-2.93	2.13	20	-0.63	1.35	20	14.8%	-1.26 [-1.95, -0.58]
Guimaraes 2013	-3.34	1.97	23	-0.2	2.21	20	14.8%	-1.48 [-2.16, -0.80]
Henriques 2019 (A)	-2.21	1.84	24	-0.6	1.9	22	15.3%	-0.85 [-1.45, -0.24]
Henriques 2019 (B)	-2.9	1.33	25	-0.6	1.9	22	15.1%	-1.39 [-2.04, -0.75]
Subtotal (95% CI)			**142**			**125**	**100.0%**	**-1.08 [-1.79, -0.37]**
Heterogeneity: Tau² = 0.76; Chi² = 39.63, df = 6 (P < 0.00001); I² = 85%								
Test for overall effect: Z = 2.98 (P = 0.003)								
5.4.7 Molar relationship								
Ardeshna 2019	-7	2.08	24	-0.41	0.71	13	48.9%	-3.71 [-4.83, -2.59]
Guimaraes 2013	-1.82	2.07	23	-1.04	1.33	20	51.1%	-0.43 [-1.04, 0.17]
Subtotal (95% CI)			**47**			**33**	**100.0%**	**-2.04 [-5.25, 1.17]**
Heterogeneity: Tau² = 5.17; Chi² = 25.42, df = 1 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 1.24 (P = 0.21)								
Test for subgroup differences: Chi² = 91.40, df = 5 (P < 0.00001), I² = 94.5%								

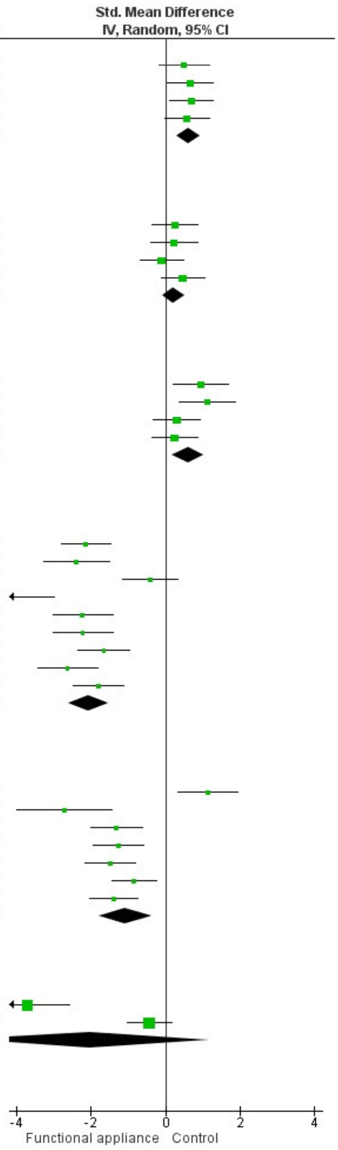

Table 15: Characteristics of included studies

Study Id	Place of study	Study Setting	Study Design	Sample Size Intervention/ Control	Age group	Gender M/F	Intervention	Control	Outcome assessed	Authors conclusions
Al-Jewair 2013[7]	New York	private practice	retrospective	64 40/24	10-17	35/29	MARA appliance	no treatment	35 landmarks	Overall, the MARA showed significant skeletal and dentoalveolar changes resulting in normalization of the Class II malocclusion
Baysal 2013[8]	Turkey	Orthodontic Clinic of Erciyes University	RCT	51 40/11		30/21	Herbst appliance n=20 Twin block n=20	no treatment	cephalometric measurements	Therapies with both appliances resulted in correction of Class II relationship, reduction of overjet, and improvement in skeletal discrepancy. The only statistically significant differences between treatment groups were recorded for mandibular incisor position and skeletal discrepancy. After treatment, incisor

										protrusion was higher in the Herbst group and skeletal discrepancy improvement was greater in the TB group
Bock 2013 [9]	Germany	Orthodontic Department at the University of Giessen	retrospective	22	12-27 years mean 15+-3.27	11/11	Herbst appliance	no treatment	molar relationship overjet midline shift	Class II subdivision Herbst treatment was similarly as successful as symmetric Class II Herbst treatment with respect to the occlusal correction
Guimaraes 2013 [10]	Brazil	Bauru Dental School, University of Sa˜o Paulo	prospective	43 23/20	11.33-16.5	20/23	Twin Force Bite Corrector	no treatment	cephalometric measurements	The appliance promotes restriction of anterior maxillary displacement without significant changes in mandibular length and position and improvement of maxillomandibular relationship without changes in facial growth and significant buccal tipping of mandibular incisors.
Alali 2014 [11]	Syria	University of Damascus, Department of Orthodontics	RCT	38 21/17	mean 13.2 years	17/21	FLMGM	no treatment	cephalometric measurements	FLMGM was effective in treating Class II/1 growing patients and produced favorable and measurable dentofacial changes. Overjet reduction was achieved by a combination of upper incisor retroclination and increase in total mandibular length associated with forward chin repositioning.
Dalci 2014 [10]	Turkey	University of Ankara, Department of Orthodontics	clinical study	30 10/10/10	-	21/9	TFBC Activator	no treatment	cephalometric measurements	The TFBC and the Activator were both successful in correcting a Class II relationship in young adults, with greater skeletal mandibular changes identified in the Activator Group and mandibular dentoalveolar changes in the Twin-Force Bite Corrector Group.
Ehsani 2015 [13]	Canada	private practice	retrospective	75 25/25/25	-	27/48	Twin block Xbow	no treatment	cephalometric measurements	Class II correction with an XBow or Twin-block followed by orthodontic brackets and archwires is achieved by a combination of dentoalveolar and skeletal effects without vertical changes

Austro 2018 [14]	Spain	private practice	prospective	85 45/40	11.3-11.7	45/40	Austro Repositioner	no treatment	cephalometric measurements	The Austro Repositioner is a FFAthat was found to be effective for the treatment of skeletal Class II malocclusion resulting from the retrusion of the mandible in both dolicho- and brachyfacial patients over the short term.
Bock 2018 [15]	Germany	Department of Orthodontics at the University of Giessen,	Retrospective	51 20/31	mean 14.4 years	29/22	Herbst multibracket appliance	no treatment	sagittal molar and canine relationship, PAR score	A very good long-term stability was seen for the occlusal outcome of Class II:2 Herbst-MBA Tx. On average mild changes had occurred during the post-Tx observation period and the long-term findings were similar as in untreated Class I controls.
Alhammadi 2019 [16]	Egypt	Department of Orthodontics, Cairo university	RCT	41 23/18	IG:11.89+-1.85 CG:11.27+-1.19	0/41	FFRD	no treatment	cephalometric measurements	The Twin Block functional appliance induced significant skeletal and pharyngeal airway changes compared to the effects induced by FFRD or by natural growth.
Ardeshna 2019 [17]	USA	Rutgers University	retrospective	37 24/13		21/16	MARA appliance	no treatment	cephalometric measurements	The MARA is effective in the treatment of Class II malocclusion, resulting in a significant decrease in overjet and correction of the Class II molar relationship. Improvement is primarily the result of dental effects of the mandibular incisor and molar and maxillary molar.
Henriques 2019 [18]	Brazil	Bauru Dental School, University of São Paulo	prospective	71 24/25/22	12.36 years	37/34	MPA Jasper Jumper	no treatment	cephalometric measurements	The JJ group presented a greater restriction of growth and anterior displacement of the maxilla and greater maxillary retrusion and the MPA group showed a significantly greater increase of mandibular effective length.
Alhoraibi 2020 [19]	USA	private practice	retrospective	120 60/60			FFRD appliance	no treatment	cephalometric measurements	This study found that the FFRD was capable of correcting Class II malocclusion in growing patients presenting at various skeletal maturational ages via different methods. FFRD induced skeletal maxillary restraint and dentoalveolar compensation

										during the pre-peak and peak growth stages.
Fontes 2020 [20]	Brazil	Bauru Dental School, University of São Paulo	retrospective	60 40/20		30/30	Jasper Jumper Twin Force	no treatment	cephalometric measurements	The dentoalveolar and soft-tissue effects of the Jasper jumper and the Twin Force Bite Corrector, followed by fixed orthodontic appliances were similar in Class II malocclusion treatment. However, the Twin Force seems to provide more skeletal effects than the Jasper Jumper, since it demonstrated greater maxillary growth restriction and mandibular length increase.
Giuca 2020 [21]	Italy	private practice	retrospective	150 75/75	9.8+-1.9	70/80	Herbst appliance	no treatment	cephalometric measurements	The study showed differences in response to treatment with the Herbst appliance depending on patient's vertical growth pattern.
Elkordy 2021 [22]	Egypt	Faculty of Dentistry, Cairo University	retrospective	46 15/15/16	11/14	-	FFRD appliance Splint FFRD	no treatment	cephalometric measurements	FFRD was successful in the treatment of Class II malocclusion through dento-alveolar changes and minimal skeletal changes. The splint-supported FFRD was equally effective as the conventional FFRD, with no significant difference in the treatment effects, except for a modest maxillary headgear effect.