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Dr. Bhagyashri Namdev Bhanuse
PG III Student, Department of Orthodontics and Dentofacial Orthopaedics, VYWS Dental College and Hospital, Amravati, Maharashtra, India

Dr. Amol Ashokrao Verulkar
H.O.D, Department of Orthodontics and Dentofacial Orthopaedics, VYWS Dental College and Hospital, Amravati, Maharashtra, India

Dr. Ratnadip Arun Lohakpure
Reader, Department of Orthodontics and Dentofacial Orthopaedics, VYWS Dental College and Hospital, Amravati, Maharashtra, India

Dr. Shruti Shatrughna Sangle
PG III Student, Department of Orthodontics and Dentofacial Orthopaedics, VYWS Dental College and Hospital, Amravati, Maharashtra, India

Corresponding Author:
Dr. Bhagyashri Namdev Bhanuse
PG III Student, Department of Orthodontics and Dentofacial Orthopaedics, VYWS Dental College and Hospital, Amravati, Maharashtra, India

Assessing the efficacy of fixed functional appliances in orthodontic patients: A systematic review

Dr. Bhagyashri Namdev Bhanuse, Dr. Amol Ashokrao Verulkar, Dr. Ratnadip Arun Lohakpure and Dr. Shruti Shatrughna Sangle

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Abstract

Introduction: The aim of this systematic review was to assess the efficacy of fixed functional appliances in orthodontic patients. The review focused on comparing pre- and post-treatment measurements across a range of skeletal, dentoalveolar, and soft tissue parameters, such as the SNA angle, SNB angle, ANB angle, incisor mandibular plane angle, upper central incisor to Sella-Nasion (SN) plane angle, overjet, and nasolabial angle.

Materials and Methods: This systematic review is based on 14 studies, collectively involving 663 individuals with skeletal class II malocclusion and retrognathic mandibles. The participants had a mean age of 13±2.6 years and were treated with various fixed functional appliances. Appliances used in studies comprises of Herbst appliance, Fixed Twin block, Forsus fatigue resistance device, Forsus nitinol flat spring, Power scope device, Advance sync device, Jasper jumper, Churro jumper.

Results: Out of the 14 studies, the pre- and post-treatment effects on the SNA angle, SNB angle, ANB angle, IMPA, U1 to SN angle, overjet, and nasolabial angle were evaluated. The sagittal correction of class II malocclusion was predominantly achieved. Statistically significant reductions were observed in the SNA angle, ANB angle, U1 to SN angle, and overjet. Meanwhile, post-treatment increases were noted in the SNB angle, IMPA, and nasolabial angle.

Conclusion: All fixed functional appliances successfully corrected class II malocclusions. It considerably causes the jaw to shift forward and downward. Although not present with every fixed functional appliance but statistics show that Fixed Functional Appliances induce is noticeable maxillary retrusion.

Keywords: Elastic modulus, flexural strength, provisional restorative materials

Introduction

The Orthodontics and Dentofacial Orthopaedics deals with the population's malocclusion prevention, interception, and correction. In clinical practice, we frequently encounter Angle's Class II Division 1 malocclusion. Treating the anteroposterior discrepancies and mandibular retrognathism associated with this malocclusion in adult patients presents a significant challenge [1]. The term "functional appliance" refers to a range of removable devices specifically designed to alter the positioning and activity of various muscle groups that influence the function and alignment of the mandible. These appliances transmit forces to the teeth and basal bone, aiding in orthodontic correction. The Orthodontic and Orthopedic changes are changes are result of altering the mandibular position sagitally and vertically which will generate altered muscular forces. Success of treatment of Class II malocclusion depends on patient obedience in wearing the removable functional appliance. Hence, in non-obedient patients, fixed functional appliances plays a role [1].

These appliances are usually used along with full-banded fixed appliances [2]. The first fixed functional appliance was introduced by Emil Herbst in 1905 [3]. Although they have made their way to the top in clinical practise in last three decades only. Today, they are used in both compliant as well as non-compliant patients for better efficacy in correcting sagittal relationship in brief time [3]. The effectiveness of fixed functional appliances after growth has ceased remains uncertain. However, similar changes in condylar growth and glenoid fossa remodelling have been observed in adult patients following Herbst therapy [1].

Fixed functional appliances are anchored to the molars at their distal end and attached mesially on the mandibular arch to maintain the mandible in a forward position. They have evolutioned from many designs from rigid to flexible versions for sake of sustaining forward mandibular position [4].

Fixed functional appliances are commonly used to correct skeletal class II cases with a retrognathic mandible. They can also be applied in skeletal class III cases with a retrognathic maxilla, leveraging any remaining growth in post-adolescent patients who have surpassed their peak pubertal growth. Additionally, by using the appliance unilaterally, functional midline shifts can be addressed [5].

The process by which a fixed functional appliance facilitates mandibular adaptation to a forward posture is similar to that of a removable functional appliance. As a tooth-borne device, it effectively influences the underlying bone through the teeth by transmitting forces generated from the continuous forward positioning of the mandible. Despite differing opinions on the concept, the primary mechanisms of action include stimulation of mandibular growth, restriction of maxillary growth, alterations in dentoalveolar structure, adaptive changes in the glenoid fossa, and modifications in neuromuscular structure and function that trigger bone remodeling [5].

The outcomes achieved with functional appliances in correcting class II malocclusion consist of approximately 60-70% dentoalveolar effects and 30-40% orthopaedic effects [5].

Materials and Methods

This systematic review encompasses studies involving 663 patients with a mean age of 13±2.6 years, all diagnosed with skeletal class II malocclusion and retrognathic mandibles. The patients were treated using various fixed functional appliances, including the Herbst appliance, fixed twin block, Forsus fatigue-resistant device, Forsus nitinol flat spring, Powerscope device, Advance sync device, Jasper jumper, and Churro jumper. The protocol for this systematic review was prospectively registered on PROSPERO.
(www.crd.york.ac,uk/PROSPERO; CRD42023413192)

Statistical analysis

Meta-analyses were conducted using a random effects model with RevMan 5.4 (The Nordic Cochrane Centre, Copenhagen). Heterogeneity was evaluated using a Q test and quantified with I^2 statistics. Comparisons between pre-treatment and post-treatment scores were made for the following variables: SNA, SNB, ANB, IMPA, U1 to SN, overjet, and nasolabial angle. Data for these variables were extracted from the selected studies. In cases of substantial heterogeneity ($I^2 > 50\%$), the random effects model was employed; otherwise, the fixed effects model was used when $I^2 \leq 50\%$.

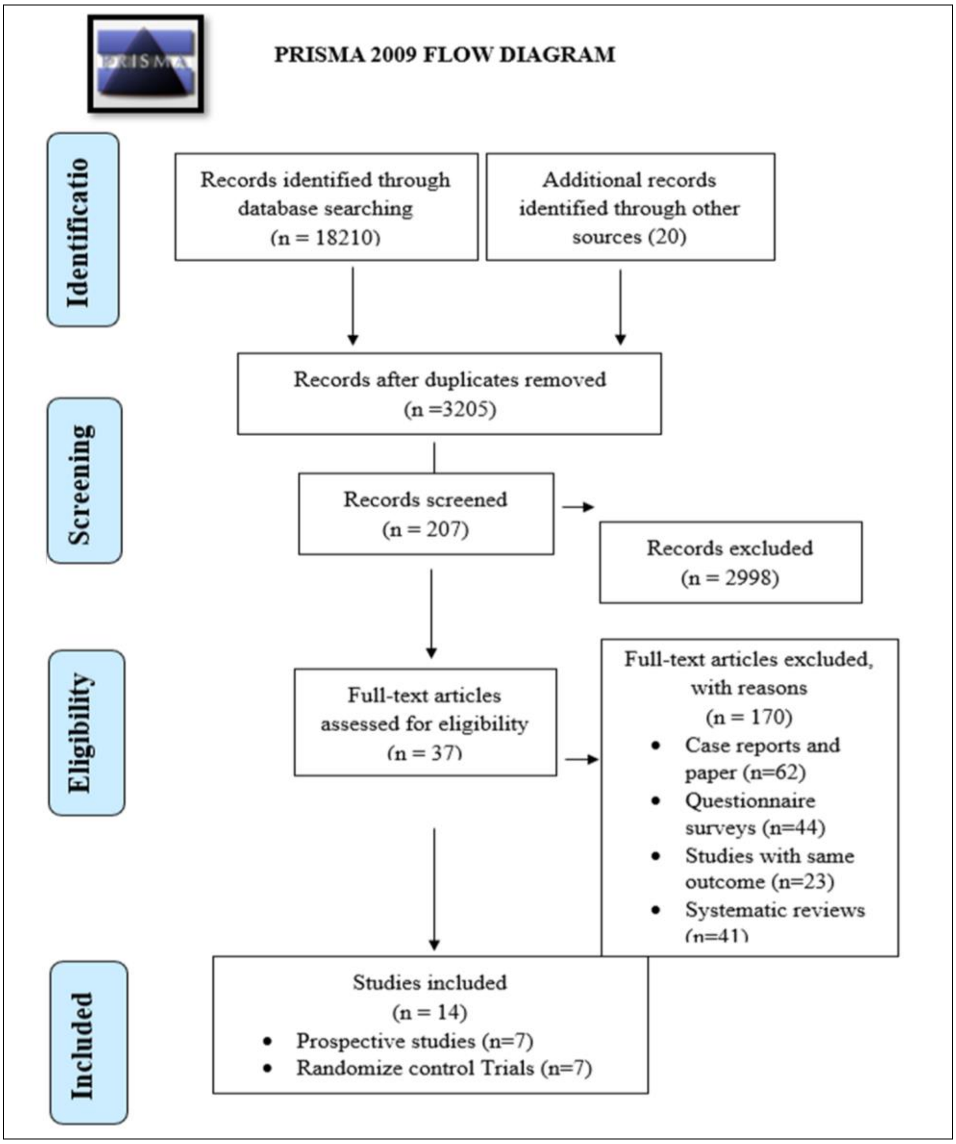


Table 1: Study Design and Patient Population in the Included Study

Sr. No.	Author	Year	Study Design	Mean age	Age range	Sample size
1	Shetty P, Shetty M, Chalapati M, Kori C, Soans CR, Murali PS *et al.*	2021	Prospective study	11.2±1.6 years	Not Reported	20
2	Pupulim DC, Henriques JF, Freitas KM, Fontes FP, Fernandes TM *et al.*	2021	Randomized Control Trial	12.39 years	Not Reported	61
3	Gandedkar NH, Shrikantaiah S, Patil AK, Baseer MA, Chng CK, Ganeshkar SV, Kambalyal P *et al.*	2019	Randomized Control Trial	13.11±0.38 years	Not Reported	16
4	Amuk NG, Baysal A, Coskun R, Kurt G *et al.*	2018	Randomized Control Trial	16.10±1.63 years	Not Reported	42
5	Aslan BI, Kucukkaraca E, Turkoz C, Dincer M *et al.*	2014	Randomized Control Trial	3.68±1.09 years	Not Reported	48
6	Sandeep Atmaramji Jethe, 2 Ravi Gupta, 3 Jayesh Rahalkar *et al.*	2013	Prospective study	Not Reported	11-16 years	6
7	Gohilot A, Pradhan T, Keluskar KM.	2013	Randomized Control Trial	13 -17 years	Not Reported	32
8	Nelson B, Hägg U, Hansen K, Bendeus M	2007	Prospective study	Not Reported	Not Reported	18
9	Karacay S, Akin E, Olmez H, Gurton AU, Sagdic D *et al.*	2006	Prospective study	13.6±1.2 years	Not Reported	48
10	Arici S, Akan H, Yakubov K, Arici N *et al.*	2006	Randomized Control Trial	12 years 7 months	Not Reported	60
11	VanLaecken R, Martin CA, Dischinger T, Razmus T, Ngan Pv *et al.*	2005	prospective cohort study	10 years 6 months±1 year 7 months for the girls 9 years 9 months±1 year 5 months for the boys	Not Reported	52
12	Read MJ, Deacon S, O'Brien K	2004	Prospective cohort study	Not Reported	Not Reported	32
13	O'brien K, Wright J, Conboy F, Sanjie Y, Mandall N, Chadwick S, Connolly I, Cook P, Birnie D, Hammond M, Harradine N	2003	Randomized Control Trial	Not Reported	11-14 years	215
14	Heinig N, Göz G.	2001	Prospective study	14.2 years	Not Reported	13

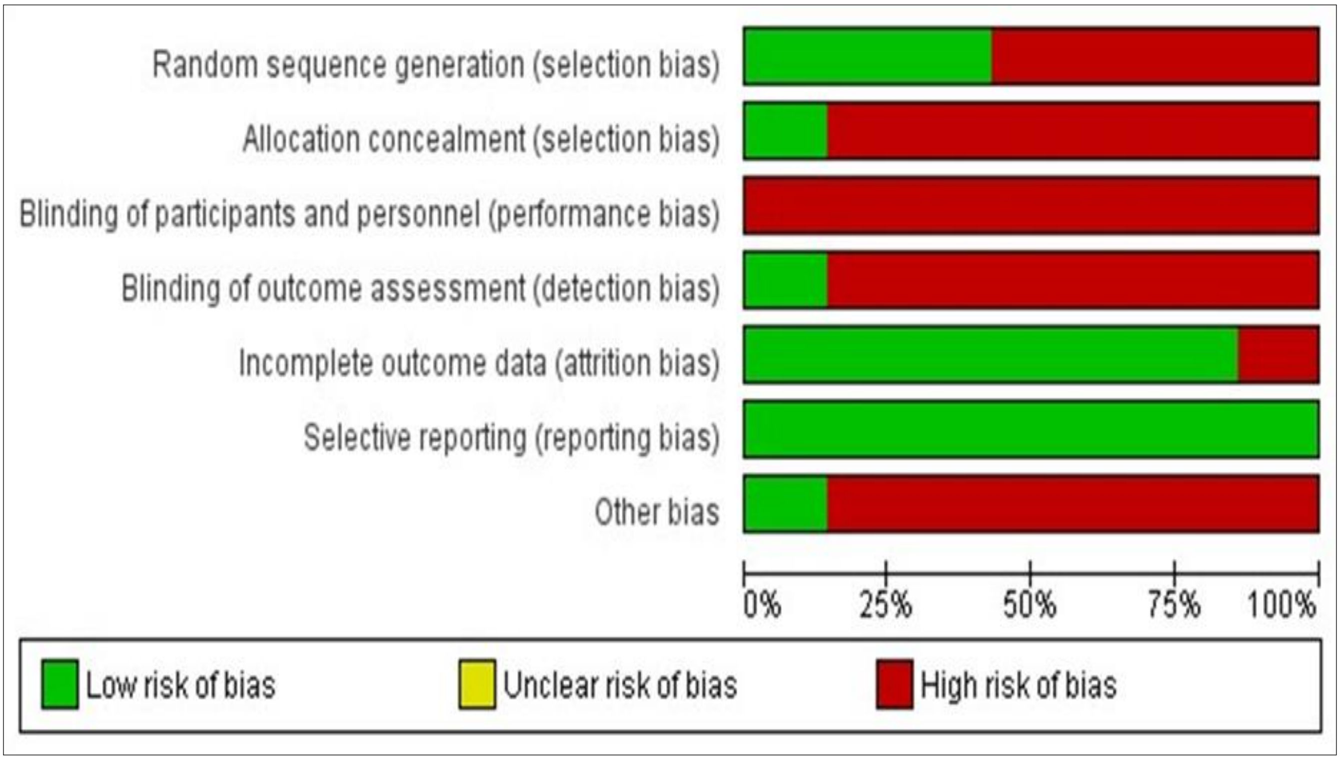


Fig 1: Risk of bias Assessment

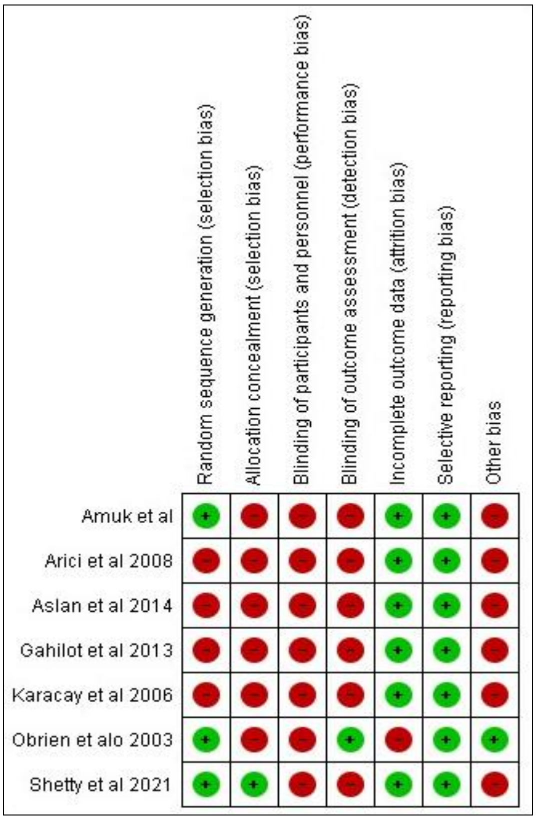


Fig 2: Risk of bias evaluation summary

Results

A total of 18,210 records were identified through database searches, with an additional 20 records found via other sources. After removing duplicates, 3,205 articles remained, from which 2,998 were excluded, leaving 207 articles for screening. Of these, 47 full-text articles were reviewed for eligibility, and 14 studies were ultimately included in this systematic review.

Among the included studies, seven were prospective, and seven were randomized controlled trials. In total, 663 patients who used various types of fixed functional appliances were analyzed.

The 14 studies assessed pre-treatment factors such as the SNA angle, SNB angle, and ANB angle, IMPA, U1 to SN angle, overjet, and nasolabial angle.

Comparison of Pre-treatment and Post-treatment SNA Angle

A meta-analysis was conducted on four studies with six comparisons that met the criteria for quantitative analysis. The results are presented in a forest plot. The heterogeneity among the studies was less than 50% ($I^2 = 0\%$), allowing for the use of a fixed-effects model. The analysis showed a slight reduction in the SNA angle post-treatment, with a mean difference of 0.70 (95% CI = -0.30 to 1.70; Z value = 1.70). However, the difference between pre-treatment and post-treatment SNA angle was statistically non-significant (P=0.17).

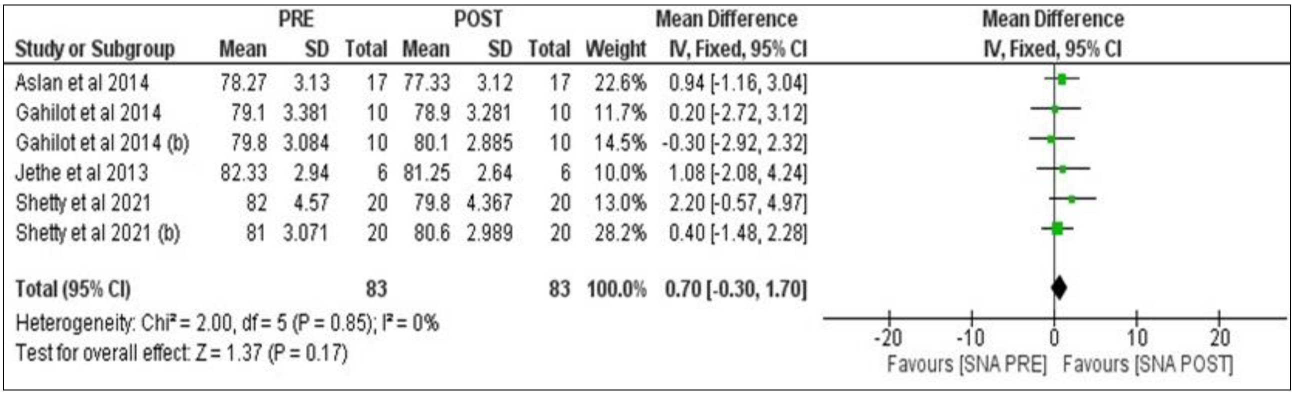


Fig 3: Pre: Pre-treatment, Post: Post-treatment, SNA: SNA Angle

Comparison of Pre-treatment and Post-treatment SNB Angle: A meta-analysis was conducted on four studies with six comparisons that provided sufficient data for quantitative analysis. The overall results are illustrated in a forest plot. The heterogeneity among the selected studies was moderate ($I^2 = 45\%$), allowing the use of a fixed-effects model. The analysis revealed an increase in the SNB angle following treatment, with a mean difference of -1.11 (95% CI = -2.05 to -0.17; Z value = 2.31). This change in SNB angle from pre-treatment to post-treatment was statistically significant (P=0.02).

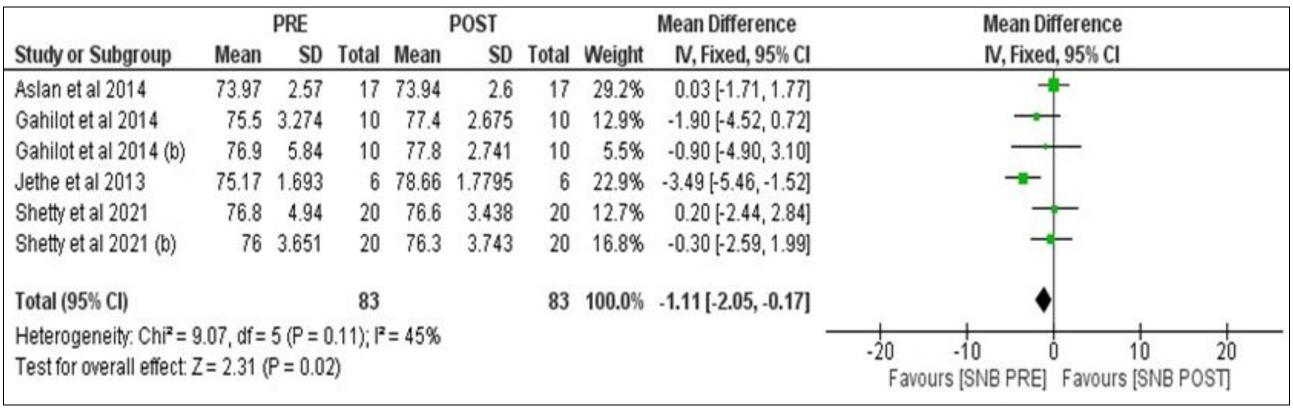
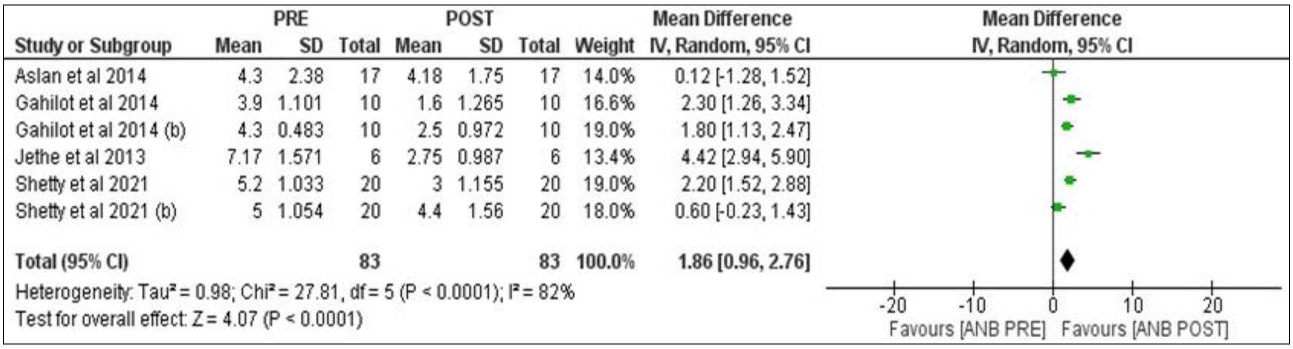


Fig 4: Pre-treatment, Post-Post treatment, SNB-Angle SNB

Comparisons of Pre-treatment and Post-treatment ANB angle
A meta-analysis was conducted on four studies with six comparisons that provided sufficient data for quantitative analysis. The results of the overall comparison are illustrated in a forest plot. Since heterogeneity across the selected studies was high (I² = 82%), a random-effects model was applied. The analysis showed a reduction in the ANB angle after treatment, with a mean difference of 1.86 (95% CI = 0.96 to 2.76; Z value = 4.07). This decrease in ANB angle from pre-treatment to post-treatment was statistically significant (p < 0.0001).

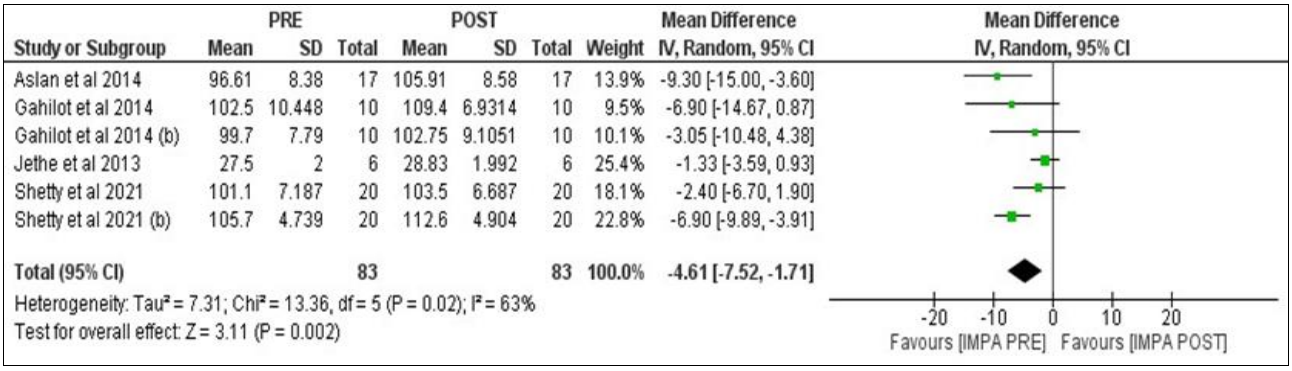


Study or Subgroup	PRE Mean	PRE SD	PRE Total	POST Mean	POST SD	POST Total	Weight	Mean Difference IV, Random, 95% CI
Aslan et al 2014	4.3	2.38	17	4.18	1.75	17	14.0%	0.12 [-1.28, 1.52]
Gahilot et al 2014	3.9	1.101	10	1.6	1.265	10	16.6%	2.30 [1.26, 3.34]
Gahilot et al 2014 (b)	4.3	0.483	10	2.5	0.972	10	19.0%	1.80 [1.13, 2.47]
Jethe et al 2013	7.17	1.571	6	2.75	0.987	6	13.4%	4.42 [2.94, 5.90]
Shetty et al 2021	5.2	1.033	20	3	1.155	20	19.0%	2.20 [1.52, 2.88]
Shetty et al 2021 (b)	5	1.054	20	4.4	1.56	20	18.0%	0.60 [-0.23, 1.43]
Total (95% CI)			**83**			**83**	**100.0%**	**1.86 [0.96, 2.76]**

Heterogeneity: Tau² = 0.98; Chi² = 27.81, df = 5 (P < 0.0001); I² = 82%
Test for overall effect: Z = 4.07 (P < 0.0001)

Fig 5: Pre-treatment, Post-Post treatment, ANB-Angle ANB

Comparisons of Pre-treatment and Post-treatment IMPA angle: A meta-analysis was carried out on four studies with six comparisons that met the criteria for quantitative analysis. The overall comparison results are displayed in a forest plot. Due to the moderate heterogeneity among the selected studies (I² = 63%), a random-effects model was applied. The analysis indicated an increase in the IMPA after treatment, with a mean difference of 4.61 (95% CI = -7.52 to -1.71; Z value = 3.11). This change in IMPA from pre-treatment to post-treatment was statistically significant (P=0.002).

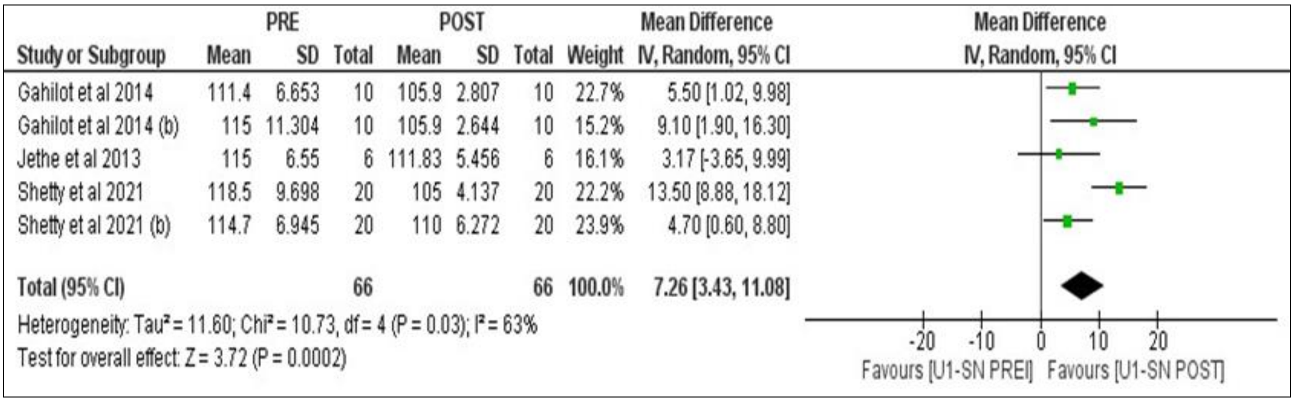


Study or Subgroup	PRE Mean	PRE SD	PRE Total	POST Mean	POST SD	POST Total	Weight	Mean Difference IV, Random, 95% CI
Aslan et al 2014	96.61	8.38	17	105.91	8.58	17	13.9%	-9.30 [-15.00, -3.60]
Gahilot et al 2014	102.5	10.448	10	109.4	6.9314	10	9.5%	-6.90 [-14.67, 0.87]
Gahilot et al 2014 (b)	99.7	7.79	10	102.75	9.1051	10	10.1%	-3.05 [-10.48, 4.38]
Jethe et al 2013	27.5	2	6	28.83	1.992	6	25.4%	-1.33 [-3.59, 0.93]
Shetty et al 2021	101.1	7.187	20	103.5	6.687	20	18.1%	-2.40 [-6.70, 1.90]
Shetty et al 2021 (b)	105.7	4.739	20	112.6	4.904	20	22.8%	-6.90 [-9.89, -3.91]
Total (95% CI)			**83**			**83**	**100.0%**	**-4.61 [-7.52, -1.71]**

Heterogeneity: Tau² = 7.31; Chi² = 13.36, df = 5 (P = 0.02); I² = 63%
Test for overall effect: Z = 3.11 (P = 0.002)

Fig 6: Pre-Pre treatment, Post-Post treatment, IMPA-Incisor Mandibular Plane Angle

Comparisons of Pre-treatment and Post-treatment U1-SN angle: A meta-analysis was carried out on four studies with six comparisons that met the criteria for quantitative analysis. The overall comparison results are displayed in a forest plot. Due to the moderate heterogeneity among the selected studies (I² = 63%), a random-effects model was applied. The analysis indicated an increase in the IMPA after treatment, with a mean difference of 4.61 (95% CI = -7.52 to -1.71; Z value = 3.11). This change in IMPA from pre-treatment to post-treatment was statistically significant (P=0.002).



Study or Subgroup	PRE Mean	PRE SD	PRE Total	POST Mean	POST SD	POST Total	Weight	Mean Difference IV, Random, 95% CI
Gahilot et al 2014	111.4	6.653	10	105.9	2.807	10	22.7%	5.50 [1.02, 9.98]
Gahilot et al 2014 (b)	115	11.304	10	105.9	2.644	10	15.2%	9.10 [1.90, 16.30]
Jethe et al 2013	115	6.55	6	111.83	5.456	6	16.1%	3.17 [-3.65, 9.99]
Shetty et al 2021	118.5	9.698	20	105	4.137	20	22.2%	13.50 [8.88, 18.12]
Shetty et al 2021 (b)	114.7	6.945	20	110	6.272	20	23.9%	4.70 [0.60, 8.80]
Total (95% CI)			**66**			**66**	**100.0%**	**7.26 [3.43, 11.08]**

Heterogeneity: Tau² = 11.60; Chi² = 10.73, df = 4 (P = 0.03); I² = 63%
Test for overall effect: Z = 3.72 (P = 0.0002)

Fig 7: Pre: Pre-treatment, Post: Post-treatment, U1-SN: Upper Incisor to SN Plane Angle

Comparisons of Pre-treatment and Post-treatment overjet
A meta-analysis was conducted on five studies with six comparisons that met the criteria for quantitative analysis. The overall comparison results are presented in a forest plot. Due to high heterogeneity among the selected studies (I² = 90%), a random-effects model was applied. The analysis

indicated a reduction in overjet post-treatment, with a mean difference of 5.08 (95% CI = 3.88 to 6.28; Z value = 8.32). This decrease in overjet from pre-treatment to post-treatment was statistically significant ($p<0.00001$).

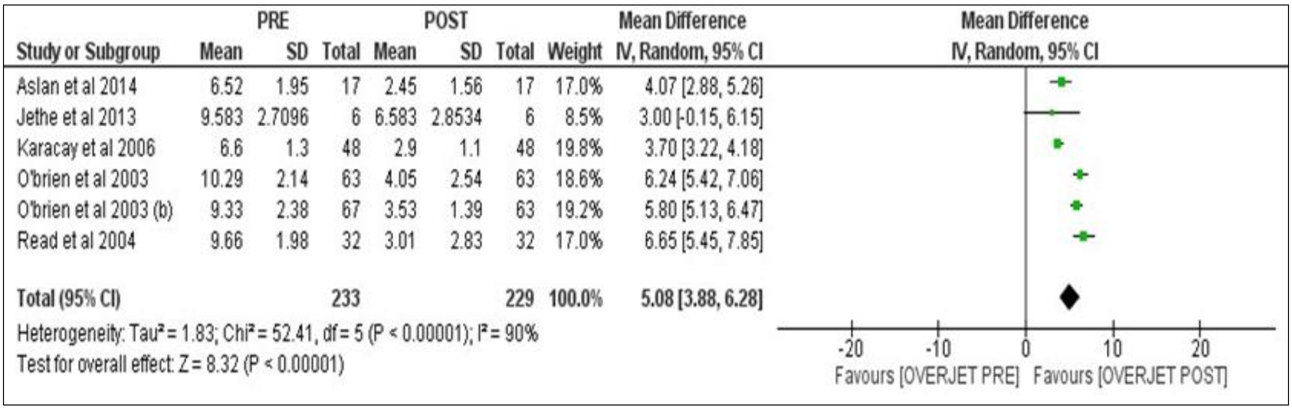


Fig 8: Pre: Pre-treatment, Post: Post-treatment, Overjet: Extent of horizontal overlap of maxillary central incisor over mandibular central incisor

Comparisons of Pre-treatment and Post-treatment nasolabial angle

A meta-analysis was conducted on five studies with six comparisons that met the criteria for quantitative analysis. The overall results are illustrated in a forest plot. Given that heterogeneity among the selected studies was high ($I^2 = 88\%$), a random-effects model was employed. The analysis indicated an increase in the nasolabial angle post-treatment, with a mean difference of -6.98 (95% CI = -16.59 to 2.63; Z value = 1.42). However, this change in the nasolabial angle from pre-treatment (Pre) to post-treatment (Post) was statistically non-significant (P=0.15).

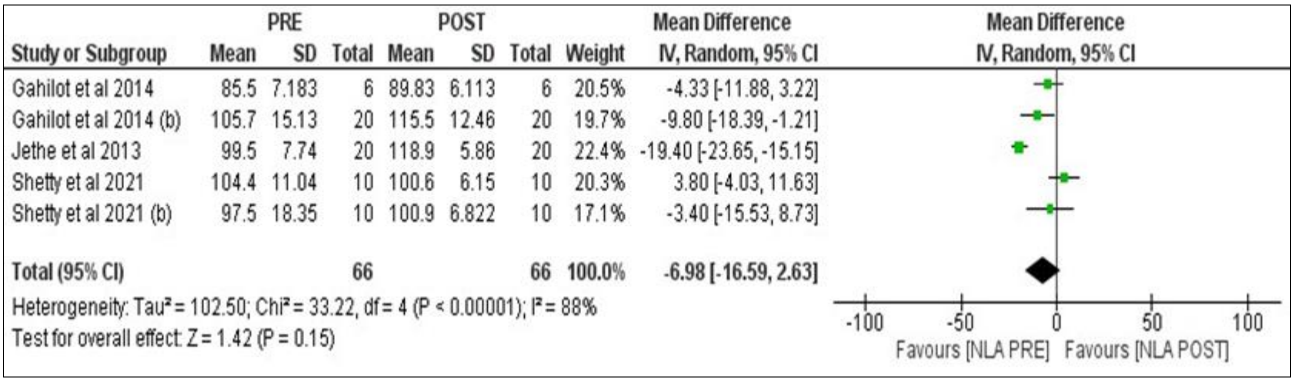


Fig 9: Pre: Pre-treatment, Post: Post-treatment, Nasolabial Angle: Angle formed by point's columella, subnasale, and labrale superius

Discussion

The aim of this systematic review is to assess the effectiveness of fixed functional appliances in orthodontic treatment. To achieve this, we compared the pre-treatment and post-treatment measurements of the SNA angle, SNB angle, and ANB angle, IMPA, U1 to SN angle, overjet, and nasolabial angle.

The effectiveness of functional appliances on the maxilla is inconsistent with many previous studies, which indicate that there is no restriction in the forward growth of the maxilla. This suggests that these appliances do not have a significant impact on limiting the forward growth of the maxilla. But there was significant maxillary growth restriction with forsus and power scope fixed functional appliances according to Prajwal shetty, Mukul Shetty, Maitreyi Chalapati et.al. The results of current systematic review showed slight restriction of maxillary growth; but this was statistically non-significant (P=0.17) [6].

This review supports study done by Ryan VanLaecken, Chris A. Martin, Terry Dischinger, *et al.* [10] that angle SNB is changed after treatment and there is jumping of the bite resulting increase in angle SNB. The forward and downward movement of mandible was observed.

Angle ANB is affected by angle SNA and SNB. It was found to be decreased in the studies post treatment as angle SNB increased [8] in few studies the reason for decreased ANB was restricted maxillary growth ie. Decrease in angle SNA along with increase in angle SNB [6, 11].

Seniz Karacay, Erol Akin, Huseyin Olmez *et al.* [11]. Narrated the decreased in IMPA or L1 to MP angle [7]. And, according to Nina Heinig, Gernot Goz [4], Prajwal shetty, Mukul Shetty, Maitreyi Chalapati *et al.* [8], Birgitta Nelson, Urban Hagg, Ken Hansen *et al.* [7], Sandeep Atmaramji Jethe, Ravi Gupta [4], IMPA was increased post treatment, suggesting the proclination of lower incisor relative to mandibular plane.

According to studies by Jethe SA, Gupta R, Rahalkar J, Khedkar SA, *et al.* [4], Shetty P, Shetty M, Chalapati M, Kori C *et al.* [6] U1 to SN angle was noticeably decreased, this systematic review favours their finding. Angle U1 to SN plane was found to be decreased and was stastically significant.

The fixed functional appliance exerts a downward and forward force, prompting adaptive movement of the mandible, which results in a decreased overjet. In this review, a significant reduction in overjet was observed post-treatment. These findings align with previous studies conducted by Aslan BI, Kucukkaraca E, Turkoz C, Dincer M [13], Jethe SA, Gupta R, Rahalkar J, Khedkar SA [4], Karacay S, Akin E, Olmez H, Gurton AU, Sagdic D [11], O'Brien K, Wright J, Conboy F, Sanjie Y, Mandall N [12], Shetty P, Shetty M, Chalapati M, Kori C, and Soans CR [6].

The change in nasolabial angle post treatment was statistically non-significant. This finding might be in accordance to the constant maxillary position i.e. angle SNA in this study was found non-significant. It also questions on the maxillary growth reduction capacity of the fix functional appliances.

Conclusion

From this systematic review and meta-analysis, we can conclude that:

- Fixed Functional Appliances may or may not lead to significant maxillary retrusion; however, a downward and forward movement of the mandible is observed.
- The forward movement of the mandible results in a reduction in overbite, but it also leads to the proclination of the lower incisors and slight retroclination of the upper incisors.
- Although slight changes were noted in the nasolabial angle, these changes were statistically non-significant.

Limitations

Due to the limited data on the effects of fixed functional appliances, this review was unable to encompass all types of fixed functional appliances. Consequently, the information presented here is based primarily on commonly used fixed functional appliances, such as the Herbst appliance, Forsus fatigue resistance device, fixed twin block, Forsus fatigue resistance device with mini screw, Jasper jumper, Churro jumper, Power Scope appliance, and acrylic splint Herbst appliance. Other fixed functional appliances not mentioned could not be included due to insufficient available data

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Conflict of Interest
Not available

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