TREATMENT EFFECTS OF MANDIBULAR ANTERIOR REPOSITIONING APPLIANCE (MARA) IN CORRECTING CLASS II MALOCCLUSION DUE TO RETROGNATHIC MANDIBLE: A SYSTEMATIC REVIEW AND META-ANALYSIS

SAGARIKA PILLAI[1*], KARTHIKRAJA SELVARAJAN[2], THANGABALU. R[3], PRABHAKAR KRISHNAN[4], SABARINATHAN J[5], VASANTHAN PALANIVEL[6]

[1]PG Resident, Department of Orthodontics and Dentofacial Orthopedics, Vinayaka mission's sankarachariyar dental college, Vinayaka Mission's Research Foundation (DU), Salem, Tamil Nadu 636308, India. Email: sagarikapillai98@gmail.com, ORCID ID: 0000-0001-8301-5555

[2]Associate Professor, Department of Orthodontics and Dentofacial Orthopedics, Vinayaka Mission's Sankarachariyar Dental College, Vinayaka Mission's Research Foundation (DU), Salem, Tamil Nadu 636308, India. Email: drkarthikrajaortho@gmail.com, ORCID ID:0000-0002-4650-8980

[3]Assistant Professor, Department of Orthodontics and Dentofacial Orthopedics, Vinayaka Mission's Sankarachariyar Dental College, Vinayaka Mission's Research Foundation (DU), Salem, Tamil Nadu, India, Email: drbalamds93@gmail.com, ORCID ID: 0009-0005-7712-2692

[4]Professor, Department of Orthodontics and Dentofacial Orthopedics, Vinayaka Mission's Sankarachariyar Dental College, Vinayaka Mission's Research Foundation (DU), Salem, Tamil Nadu 636308, India. Email: drprabhakar84@gmail.com

[5]Professor, Department of Orthodontics and Dentofacial Orthopedics, Vinayaka Mission's Sankarachariyar Dental College, Vinayaka Mission's Research Foundation (DU), Salem, Tamil Nadu 636308, India. Email: orthosat@gmail.com, ORCID ID: 0009 0004 3531 2378

[6]Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, Vinayaka Mission's Sankarachariyar Dental College, Vinayaka Mission's Research Foundation (DU), Salem, Tamil Nadu 636308, India. Email: orthovasu@gmail.com, ORCID ID: 0000-0001-8566-0734

***Corresponding Author**

Email: : drkarthikrajaortho@gmail.com

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ABSTRACT

Objectives: Functional appliances are commonly used to treat Class II malocclusion resulting from mandibular retrusion. The Mandibular Anterior Repositioning Appliance (MARA) offers a compliance-free alternative; yet, its effectiveness relative to other functional appliances is still unclear. This systematic review quantitatively evaluated the impacts of MARA on skeletal, dental, and soft tissue structures in growing patients with Class II malocclusion, comparing it to both removable and fixed functional appliances.

Materials and Methods: Electronic searches were conducted in PubMed Central, Scopus, Web of Science,

Cochrane Library, and LILACS for English-language studies published up to 2025. Two reviewers independently performed study selection using Rayyan in blind mode, with disagreements resolved by a third reviewer. Randomised controlled trials and controlled clinical trials evaluating skeletal, dental, or soft tissue effects of MARA were included. Data synthesis was performed using Review Manager (RevMan 5.4™), and risk of bias was assessed using the ROBINS-I tool.

Results: Six controlled clinical trials involving 370 patients aged 9–15 years were included. When compared to removable functional appliances, MARA produced similar skeletal outcomes, such as greater mandibular length and a smaller ANB angle, with no statistically significant differences. In comparison to fixed functional appliances, MARA showed similar skeletal outcomes, with greater maxillary incisor retroclination and skeletal maxillary restriction.

Conclusions: MARA offers skeletal correction similar to removable and fixed functional appliances, but with less reliance on patient compliance.

Keywords: Mandibular anterior repositioning appliance; Class II malocclusion; retrognathic mandible; removable functional appliance; fixed functional appliance.

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INTRODUCTION

The global occurrence of Class II malocclusion differs significantly because of variations in ethnicity, age, and diagnostic standards. The worldwide occurrence of Class II malocclusion in the permanent teeth is approximately 19.56%, with reported values ranging from 2% to 63%.[1–3] Studies conducted across different regions of India report a prevalence rate of approximately 15% to 25% among children and adolescents.[4]

Class II malocclusion encompasses a heterogeneous group of conditions, including Division 1 and Division 2 subtypes, as well as cases arising from maxillary prognathism, mandibular retrognathism, or a combination of both. However, from a clinical and therapeutic perspective, functional appliance therapy is mainly recommended for growing patients who have Class II malocclusion caused by a retruded mandible, most frequently manifesting as Class II Division 1 malocclusion.[5]

These individuals often face functional challenges, including difficulties with chewing, speech impairments, and a higher risk of trauma to their protruded anterior teeth.[6] Numerous studies have shown that children and adolescents with Class II malocclusion report significantly lower self-esteem and are more prone to bullying and social isolation compared to their peers.[7] This negative social impact can extend into adulthood, affecting professional opportunities and overall quality of life.[8] Functional appliances are indicated in mixed and early permanent dentition, followed by comprehensive orthodontic treatment.[9] The success of removable appliances is highly dependent on

patient compliance, which often poses significant challenges, especially in younger, less cooperative individuals.[10]

Conventional removable functional appliances such as the Twin Block, Activator, Bionator, and Frankel have been widely researched and are commonly employed to correct Class II malocclusion. These appliances primarily rely on patient compliance and have demonstrated favourable skeletal effects, particularly mandibular advancement during growth. However, variability in wear time often influences treatment outcomes. Fixed functional appliances were subsequently introduced to overcome compliance issues, providing continuous mandibular advancement and more consistent results. Among these, the Herbst appliance is one of the earliest and most extensively studied, producing both dentoalveolar and skeletal adaptations during growth.[11-13] Subsequent innovations, including the Jasper Jumper, Twin Force Bite Corrector, and Forsus Fatigue Resistant Device, have aimed to improve patient comfort, simplify fabrication, and reduce appliance breakage.[14,15] Contemporary systematic reviews further indicate that fixed functional appliances produce significant dentoalveolar changes with adjunctive skeletal effects, and recent innovations such as skeletal anchorage aim to enhance these outcomes.[16]

In this context, the Mandibular Anterior Repositioning Appliance (MARA) was created as a fixed, non-compliance -dependent option that merges the benefits of continuous mandibular advancement with more straightforward clinical handling.[17] Although widely used in practice, considerable inconsistency persists in the reported results and treatment outcomes associated with the MARA appliance in current literature. A thorough and methodical assessment of the available evidence is necessary to accurately evaluate MARA's effectiveness in correcting Class II malocclusions.

Objectives:

This systematic review aims to assess the impacts of the Mandibular Anterior Repositioning Appliance (MARA) on skeletal, dental, and soft-tissue structures in growing individuals with Class II malocclusion resulting from mandibular retrusion.

MATERIALS AND METHODS:

Protocol registration

This systematic review adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The review protocol was prospectively registered in the PROSPERO database under the registration number CRD42024606331.

Eligibility criteria

The review question is 'What are the treatment effects of the Mandibular Anterior Repositioning Appliance (MARA) on skeletal, dental, and soft tissue parameters in growing patients with Class II malocclusion due to mandibular retrusion, compared with untreated controls or other functional appliances?'

The PICOS framework, covering Population, Intervention, Comparison, Outcome, and Study design, was established to guide the search strategy and define the inclusion criteria for selecting relevant studies (Table 1).

Information sources and search strategy

A comprehensive search was carried out across PubMed Central, Scopus, Web of Science, Cochrane Library and LILACS. Two reviewers (SP, KR) independently conducted the search, screening, and study selection. A combination of Medical Subject Headings (MeSH) and free-text terms was used (Supplementary Table 1). All retrieved records were imported into Rayyan.ai for duplicate removal and

blinded screening of titles, abstracts, and full texts. Discrepancies were resolved through discussion, and unresolved disagreements were adjudicated by a third reviewer (TR). During full-text assessment, the same reviewers independently applied the eligibility criteria to confirm final study inclusion. The search was limited to studies published in English up to 2025.

Data extraction

Standardised data extraction sheets were prepared, and two investigators (SP and KR) independently collected the relevant data. The extracted information included the study design and setting, participant demographics (such as patient age, sample size, and grouping), details of the interventions, treatment duration, and reported outcomes (Table 2).

Risk of bias/quality assessment in individual studies

In accordance with the Cochrane Handbook's guidelines, two investigators assessed the risk of bias using the ROBINS-I tool containing seven domains for non-randomised prospective clinical trials.[18,19] A third reviewer was consulted to reach a final consensus through a detailed discussion whenever there was a disagreement between the authors.

Summary measures and approach to synthesis

Meta-analysis was conducted using Review Manager (RevMan) version 5.4. The standardised mean difference (SMD) with 95% confidence intervals (CIs) was calculated for continuous outcomes using a random-effects, inverse variance model. Heterogeneity was evaluated through visual inspection of forest plots, Cochran's Q test (Chi-square, p-value), and the I^2 statistic. Data were combined when studies reported comparable interventions and outcomes, and means with standard deviations were directly extracted from the included studies. Since fewer than 10 studies were available, assessment of publication bias (e.g., funnel plots or Egger's test) was not performed, in accordance with Cochrane guidelines.

RESULTS

Included Studies: Selection and Characteristics

A total of 1395 records were identified through electronic database searches. After removing 226 duplicates in Rayyan, 1169 unique records remained. Title and abstract screening by two independent reviewers (SP, KR) excluded 1153 studies deemed irrelevant. The full texts of 16 articles were assessed in detail, of which 10 did not meet the eligibility criteria. Ultimately, six studies fulfilled the inclusion criteria and were included for qualitative and quantitative analysis. The study selection process is illustrated in **Figure 1** (PRISMA flow diagram).

All six studies were controlled clinical trials comprising 370 participants aged 9–15 years. MARA was compared with both removable functional appliances (Twin Block, Bionator, Activator with headgear, Frankel) and fixed functional appliances (Herbst, Advansync, Forsus) **(Table 2).**

Risk of Bias within Studies

All included studies were assessed as having low to moderate risk of bias **(Table 3)**. The primary sources of bias were the incomplete control of baseline differences between groups, particularly variations in skeletal pattern and growth stage, which could have influenced treatment outcomes.

Systematic Review Findings

MARA versus Removable Functional Appliances (RFA)

Skeletal changes

In the MARA group, the maximum sagittal increase

in mandibular length was 7.79 ± 4.81mm and in the RFA group (AcHg) by 8.38 ± 2. 94mm. The maximum increase in SNB angle was 1.1 ± 1.4mm in the MARA group and in the RFA group (Twin block) by 0.80± 2.08 mm. The maximum decrease in ANB angle in the MARA group was -1.4 ± 1.4 mm, and in the RFA group(AcHg) by -2.43 ± 1.65 mm. The maximum decrease in SNA value in the MARA group and RFA group(AcHg) is -1.39 mm and -1.87 ± 2.18 mm, respectively. The maximum sagittal decrease in maxillary length in the MARA group and RFA (Twin block) was 2.28 ± 3.66mm and 3.08±6.45 mm, respectively. The maximum increase in FMA in the MARA group and RFA group (AcHg) is 1.77±2.74mm and 0.60 ± 4.38 mm, respectively. **(Table 4)**

Dental changes

In the MARA group, the maximum retraction of the upper incisors and distalization of the upper molars were -3.34 ± 8.07 mm and 2.71 ± 1.09 mm, respectively; in the RFA group (AcHg), these values were -4.19 ± 7.98 mm and 2.11 ± 2.01 mm, respectively. In the MARA group, the minimum retraction of upper incisors and distal movement of upper molars were -1.02 ± 5.37 mm and 0.1 ± 2.9 mm, respectively; in the RFA group (Twin Block), these values were -3.13 ± 5.38 mm and 1.56 ± 2.23 mm, respectively. The maximum proclination of lower incisors and mesial movement of lower molars in the MARA group were 3.9 ± 3.2 mm and 3.1 ± 1.94 mm, respectively; in the RFA group (Twin Block), these were 0.71 mm and 2.66 ± 2.19 mm, respectively. The minimum proclination of lower incisors and mesialisation of lower molars were 2.46 mm and 1.11 ± 1.64 mm, respectively, in the MARA group and 0.53 mm and 2.47 ± 1.33mm, respectively in the RFA group Bionator and AcHg)**(Table 4)**

Soft tissue changes

Studies by Brito DBA et al[18], Siara olds et al[20] and Bastani et al[19] evaluated the soft tissue changes. The maximum increase in nasolabial angle in the MARA group is 5.03 ± 7.79 (°) and in the RFA group (AcHg) is 3.24 ± 9.22(°), and a minimum of 1.00 ± 9.20(°) in the MARA group and 0.41 (°) (Twinblock). The maximum decrease in upper lip position is -1.81 ± 1.73 mm in the MARA group and -1.88 ± 1.68mmin the RFA group (AcHg), and a minimum decrease of -0.2 mm in the MARA group and -0.29 mm in the RFA group (Bionator). The maximum increase in lower lip position in the MARA group is -0.58 ± 1.42 mm and 1.09 ± 7.15mm in the RFA group(Twinblock). The minimum increase of lower lip position in the MARA group is 0.19 ± 1.37 mm and 0.01 ± 2.77 mm in the RFA group (AcHg). **(Table 4)**

MARA versus Fixed Functional Appliances (FFA)

Skeletal changes

The maximum increase in mandibular length was 9.11 ± 4.33 mm and 7.90 ± 3.26 mm in the MARA group and FFA group (Forsus), respectively. The maximum increase in SNB angle was 1.5 ± 1.6 mm in the MARA group and 1.7 ± 1.7 mm in the FFA group (Herbst). The maximum decrease in ANB angle was -1.4 ± 1.4 mm in the MARA group and -2.15 ± 2.26 mm in the FFA group (Forsus). The maximum and minimum decreases in SNA value are -1.39 mm and -1.6 ± 2.4 mm, respectively in the MARA and FFA group(Advansync) respectively. The maximum decrease in maxillary length is 4.32 ± 3.17 mm and 3.28 ± 2.12 mm in the MARA and FFA group (Forsus), respectively. The maximum and minimum increases in FMA were 0.93 mm and 1.0 ± 2.7 mm, respectively, in the MARA and FFA groups (Advansync). (Table 5)

Dental Changes

In the MARA group, the maximum retraction of the upper incisors and distal movement of the upper molars were -2.3 ± 9.4 mm and 4.11 ± 2.11 mm, respectively. In the FFA group (Advansync and Forsus), these values were -8.4 ± 4.7 mm and 2.11 ± 2.47 mm, respectively. The minimum retraction of upper incisors and distal movement of upper molars in the MARA group were 1.07 mm and 0.1 ± 2.9 mm, respectively, while in the FFA group (Herbst and Forsus), they were -1.9 mm and -1.54 ± 4.85 mm, respectively. The maximum proclination of lower incisors and mesial movement of lower molars in the MARA group were 5.4 ± 5.9 mm and 3.71 ± 2.64 mm, respectively, and in the FFA group (Advansync, Forsus), they were 5.3 ± 3.6 mm and 3.78 ± 2.70 mm, respectively. In the MARA group, the minimum proclination of lower incisors and mesialization of lower molars were 2.46 mm and -0.6 ± 3.37 mm, respectively; in the FFA group, these values were 0.32 mm and -1.34 ± 5.57 mm, respectively (Herbst, Forsus). Table 5)

Soft tissue changes

Studies by Siara olds 20et al and Nogueria et al[23] evaluated the soft tissue changes. The maximum increase in nasolabial angle was 3.29 ± 8.19° in the MARA group and 1.62° in the FFA group (Herbst), with a minimum of -1.15° in the MARA group and 0.65 ± 7.64° in the FFA group (Forsus). The MARA group showed a maximum upper lip position decrease of -2.91 ± 1.69 mm, while the FFA group (Forsus) showed -1.3 ± 0.96 mm; the minimum decreases were -0.2 mm for MARA and -0.98 mm for FFA (Herbst). The maximum increase in lower lip position was -1.32 ± 1.9 mm in the MARA group and 0.72 ± 1.84 mm in the FFA (Forsus) group. The minimum increase of lower lip position in the MARA group is 0.39 mm and -0.20 mm in the FFA group (Herbst). **(Table 5)**

META-ANALYSIS

MARA versus Removable Functional Appliances (RFA)

Pooled analysis revealed no significant differences between MARA and RFA in mandibular skeletal effects (SNB, CO-GN), maxillary skeletal effects (SNA, Co-A), sagittal (ANB), vertical (FMA, SN-GoGn)**(figure 2a,2b),** dental (incisor inclination) **(figure 3)**, or soft tissue parameters (nasolabial angle, upper and lower lip position) **(figure 4)**. Both appliances were equally effective, with no clinically meaningful advantage of one over the other. Heterogeneity was low (I^2 = 0–28%), indicating consistent outcomes.

MARA versus Fixed Functional Appliances (FFA)

Meta-analysis showed no significant differences between MARA and FFA in Co-Gn, SNB, ANB, SNA, FMA, or lower incisor inclination, with heterogeneity ranging from 0% to 82%. However, MARA demonstrated a significantly greater restriction of maxillary length at Co-A (SMD = 0.40; 95% CI: 0.10–0.70; p = 0.009; I^2 = 0%) **(figure 5a,5b)**. In addition, upper incisors were significantly more retroclined in the MARA group compared with FFA (SMD = –1.19; 95% CI: –1.95 to –0.43; p = 0.002; I^2 = 0%) **(figure 6)**.

DISCUSSION:

Summary of Evidence

This systematic review and meta-analysis evaluated the impacts of the MARA appliance on skeletal, dental, and soft tissue structures, comparing it to both removable and fixed functional appliances in the treatment of Class II, Division I malocclusion.

MARA versus Removable Functional Appliances

MARA was compared with Twin Block, Bionator, Frankel, and Activator with headgear. Pooled

analysis showed a slight, non-significant advantage for MARA in SNA, whereas Brito DBA et al[20] reported significantly greater maxillary growth restriction with Activator–headgear (AcHg), a finding consistent with its known restrictive effects. The limited maxillary restriction observed with MARA may be attributable to maxillary incisor retrusion altering A-point position and masking skeletal changes, suggesting that adjunctive headgear may be required when substantial maxillary restriction is desired. The difference in age between the AcHg group and the MARA group would have contributed to the difference in maxillary growth restriction. Although MARA tended to advance the mandible (SNB), differences compared with removable functional appliances and changes in ANB were not statistically significant, while greater Class II correction with AcHg was again attributed to enhanced maxillary restriction (Figure 2a). No significant intergroup differences were observed in maxillary (Co-A) or mandibular (Co-Gn) lengths. Similarly, Siara-Olds et al[22] reported no Co-A reduction with MARA. Pangrazio-Kulbersh et al[24] observed increased mandibular length with Frankel therapy compared to MARA, possibly reflecting posterior condylar growth during functional treatment. Meta-analysis also demonstrated no significant differences in vertical skeletal parameters (FMA, SN-GoGn), although Bastani et al[21] reported increases in FH-MP and occlusal plane angles with MARA compared with Twin Block, likely due to dentoalveolar effects (Figure 2b). A recent systematic review by Bhanuse et al. similarly reports minimal and inconsistent vertical skeletal changes with functional appliance therapy, emphasising that vertical effects are largely patient-dependent rather than appliance-specific.[26]

In the present review, it was observed that the MARA did not result in significant maxillary incisor retroclination or mandibular incisor proclination (Figure 3). MARA exerts its effect primarily through forward mandibular positioning, promoting adaptive skeletal changes at the condyle and glenoid fossa, along with occlusal guidance. Consequently, dentoalveolar changes—particularly proclination of mandibular incisors and retroclination of maxillary incisors—tend to be less pronounced compared with other functional appliances. This may be attributed to the rigid, fixed design of MARA, which delivers continuous orthopaedic forces while minimising intermittent patient-dependent forces, thereby reducing dental compensation.[26] This makes MARA a favourable option when the treatment goal is to achieve skeletal correction with minimal undesirable changes in incisor inclination, which could otherwise affect long-term stability and facial esthetics. Bastani et al.[21] reported significantly greater mandibular incisor proclination with MARA compared to removable functional appliances, highlighting the variability in dentoalveolar response depending on appliance design and treatment mechanics. Similarly, Brito DBA et al.[20] found comparable patterns of maxillary incisor retrusion between MARA and activator–headgear therapy, suggesting that maxillary incisor changes may be influenced more by treatment mechanics than by appliance type alone (Figure 3).

Studies by Brito DBA et al[20], Siara-Olds et al[22], and Bastani et al[21] reported no significant soft-tissue differences between MARA and RFAs, likely because both appliances produce similar skeletal corrections and soft-tissue adaptation is influenced by individual variability, growth potential, and soft-tissue thickness (Figure 4). As functional appliances primarily affect skeletal and dentoalveolar structures, soft-tissue changes are generally

secondary and less predictable. Recent evidence also supports that soft-tissue outcomes are weakly correlated with underlying skeletal changes and are influenced by individual soft-tissue characteristics.[26] Therefore, appliance selection need not rely on expected soft-tissue outcomes but rather on factors such as patient compliance, comfort, and treatment goals.

MARA versus Fixed Functional Appliances

MARA was compared with Herbst, AdvanSync, and Forsus. The pooled analysis showed no significant differences in SNA, SNB, or ANB. Although MARA exhibited slightly more maxillary restriction than FFAs, this was not statistically significant. Thikriat et al[23] and Pangrazio et al[24] reported greater maxillary restriction with AdvanSync and Herbst, consistent with previous evidence of their stronger "headgear effect" (Figure 5a).

Recent systematic reviews confirm that differences among fixed functional appliances are generally small, with most appliances demonstrating comparable skeletal effects and treatment outcomes, and variations primarily reflecting differences in dentoalveolar response rather than true skeletal modification.[26,27] The meta-analysis showed no significant differences in mandibular length (Co-Gn). A statistically significant decrease in maxillary length was noted in the MARA group when compared with other fixed functional appliances (Co-A). Although the magnitude of difference between MARA and other FFAs is minimal, its clinical relevance lies in demonstrating that MARA may provide a marginally stronger orthopaedic effect on the maxilla. This could be attributed to its design, which postures the mandible forward in a continuous manner, thereby delivering sustained restraining forces on the maxilla. No significant differences in vertical skeletal parameters, such as FMA, were observed (Figure 5b).

Regarding incisor inclination, meta-analysis showed no significant differences between groups in lower incisor proclination (IMPA). Upper incisors were significantly more retroclined in the MARA group compared with FFA. The observed changes in upper incisor inclination, while statistically significant, may primarily reflect dentoalveolar compensation rather than true skeletal modification. From a clinical perspective, these differences are generally manageable through routine orthodontic mechanics and are unlikely to be a decisive factor in selecting one treatment modality over another. However, Thikriat et al[23] reported greater maxillary incisor retroclination with AdvanSync, while MARA caused more mandibular incisor proclination than Forsus, aligning with its moderate maxillary restriction and overjet correction mechanism (Figure 6). These findings are consistent with recent literature indicating that incisor inclination changes are largely appliance-dependent and influenced by anchorage design and force systems.[26,27]

Siara-Olds et al[22] reported greater upper lip retrusion and less lower lip protrusion with MARA compared to FFAs, with no significant difference in the nasolabial angle. Upper lip retrusion may result from maxillary incisor control and its secondary influence on lip position. The absence of nasolabial angle changes highlights the variability and unpredictability of soft-tissue adaptation, which depends on skeletal and dental changes as well as soft-tissue thickness and elasticity. Overall, MARA-related soft-tissue effects are mild and should not be a primary factor in appliance selection, as aesthetic benefits are subtle and patient-dependent.

Moderate to high heterogeneity (I^2) observed in the analyses is likely multifactorial and may be attributed to both clinical and methodological

differences among the included studies. Variations in treatment protocols, including differences in appliance design, force systems, duration of therapy, and adjunctive mechanics, may have contributed to differences in treatment outcomes. In addition, treatment timing differed across studies, as certain protocols, such as activator-headgear combinations, are typically initiated during the early mixed dentition, whereas appliances such as MARA are commonly used during the permanent dentition stage. Differences in skeletal maturity and timing relative to the pubertal growth spurt may therefore influence both skeletal and dentoalveolar responses. Population-related factors, including age, sex distribution, growth potential, severity of Class II malocclusion, and vertical skeletal pattern, may also have contributed to variability in effect sizes. Furthermore, differences in cephalometric landmarks and measurement techniques across studies could have introduced methodological variability. In studies involving removable functional appliances, variations in patient compliance may have additionally influenced treatment outcomes. These sources of heterogeneity are inherent to orthodontic clinical research and should be considered when interpreting pooled estimates. Accordingly, analyses with substantial heterogeneity were interpreted with caution, with greater emphasis placed on overall clinical trends and relevance rather than solely on statistical significance.

A potential influence of publication bias and small-study effects should be considered when interpreting the findings. Due to the limited number of included studies, formal assessment methods (such as funnel plot analysis) were not reliable. However, it is possible that studies with statistically significant or favourable outcomes are more likely to be published, while smaller studies may overestimate treatment effects. Therefore, the results should be interpreted with caution, particularly in analyses based on a small number of studies.

LIMITATIONS

All included studies were controlled clinical trials, most of which were retrospective in nature, and no randomised controlled trials (RCTs) were identified. The absence of RCTs represents a significant limitation, as non-randomised study designs are more susceptible to selection bias and confounding factors. In growing patients, the lack of randomisation may have influenced the observed skeletal outcomes due to variations in growth potential, treatment timing, and baseline characteristics. Functional appliance therapy is highly dependent on the timing of skeletal growth, particularly the pubertal growth peak. In the present review, only three of the included studies explicitly reported treatment during the peak growth phase, while the remaining studies did not specify the skeletal maturity status of participants. This lack of uniform reporting limits the ability to ensure comparability between intervention and control groups across studies. Variations in growth timing and baseline skeletal discrepancies may have acted as potential confounding factors, influencing the observed treatment outcomes.

CONCLUSION

Within the constraints of the available evidence, the Mandibular Anterior Repositioning Appliance (MARA) shows dental, skeletal, and soft tissue effects similar to both removable and fixed functional appliances in treating Class II malocclusion caused by mandibular retrusion.

The primary differences observed are related to dentoalveolar effects, particularly maxillary incisor retroclination and skeletal effects, particularly

maxillary restriction, compared to other fixed functional appliances rather than significant variations in skeletal correction.

Given the similarity in skeletal outcomes, appliance selection should be based on individual patient factors, including compliance, growth potential, anchorage requirements, and desired dental effects. MARA may be particularly advantageous in non-compliant patients due to its fixed design, whereas removable appliances may offer greater flexibility in specific clinical scenarios.

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ORCID ID

Author 1-0000-0001-8301-5555

Author 2 -0000-0002-4650-8980

Author 3-0009-0005-7712-2692

Author 4-0000-0001-5575-8255

Author 5-0009 0004 3531 2378

Author 6-0000-0001-8566-0734

Author contributions

Author 1: Study selection process, database assessment, study design and conceptualisation.

Author 2: Study design, database assessment, Conceptualisation

Author 3: Risk of bias assessment and methodological guidance.

Author 4: supervision and validation

Author 5: supervision and validation

Author 6: supervision and validation

All authors read and approved the final manuscript.

All authors agree to be accountable for all aspects of the work

Data availability statement

Data is available on request from the corresponding author

Ethical approval

Not applicable

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Abbreviations

MARA- Mandibular anterior repositioning appliance

ROBINS-I tool-risk of bias in non-randomised studies of interventions

PRISMA -Preferred Reporting Items for Systematic Reviews and Meta-Analyses

MeSH-Medical Subject Headings

RevMan-Review Manager

SMD -standardised mean difference

CI- confidence intervals

AcHg-Activator–headgear

RFA-removable functional appliance

FFA – fixed functional appliance

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Figure legends

Figure 1: Prisma Flow Chart

Figure 2a: Mara Versus Removable Functional Appliance (Skeletal)

Figure 2b: Mara Versus Removable Functional Appliance (Skeletal)

Figure 3: Mara Versus Removable Functional Appliance (Dental)

Figure 4: Mara Versus Removable Functional Appliance (Soft Tissue)

Figure 5a: Mara Versus Fixed Functional Appliance (Skeletal)

Figure 5b: Mara Versus Fixed Functional Appliance (Skeletal)

Figure 6: Mara Versus Fixed Functional Appliance (Dental**)**

FIGURES

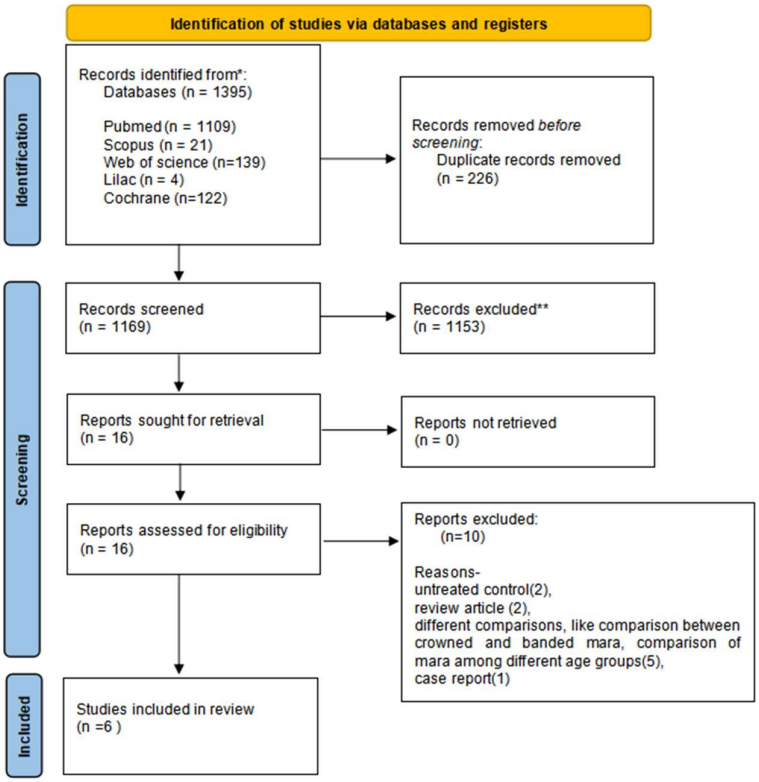


FIG 2a : MARA VERSUS REMOVABLE FUNCTIONAL APPLIANCE (SKELETAL)

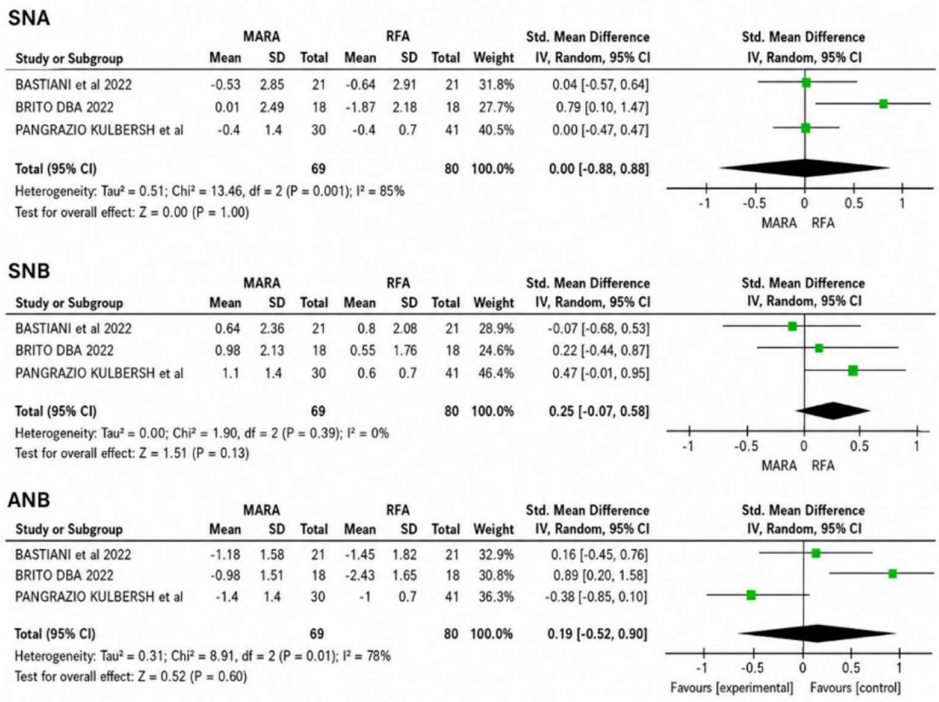


FIG 2b

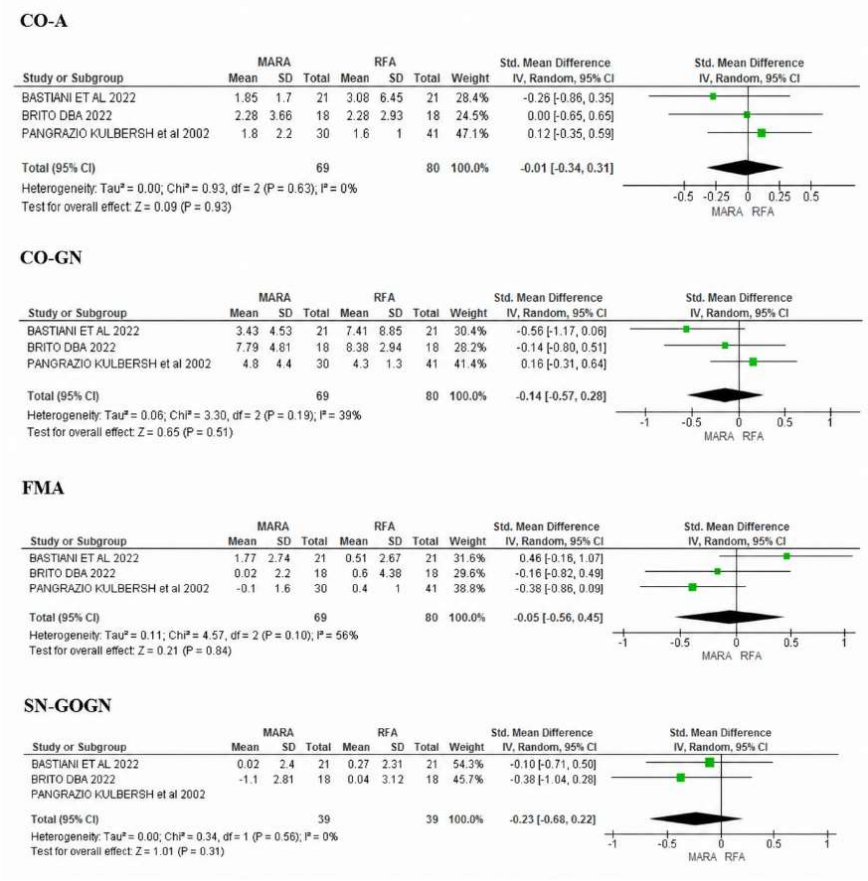


FIG 3 : MARA VERSUS REMOVABLE FUNCTIONAL APPLIANCE (DENTAL)

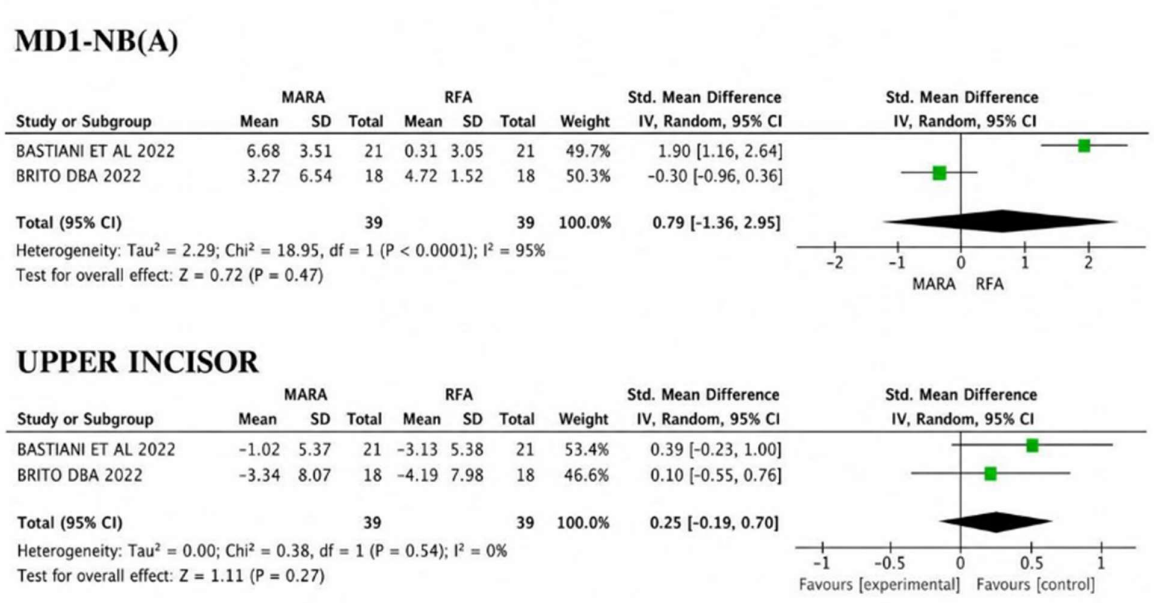


FIG 4 : MARA VERSUS REMOVABLE FUNCTIONAL APPLIANCE (SOFT TISSUE)

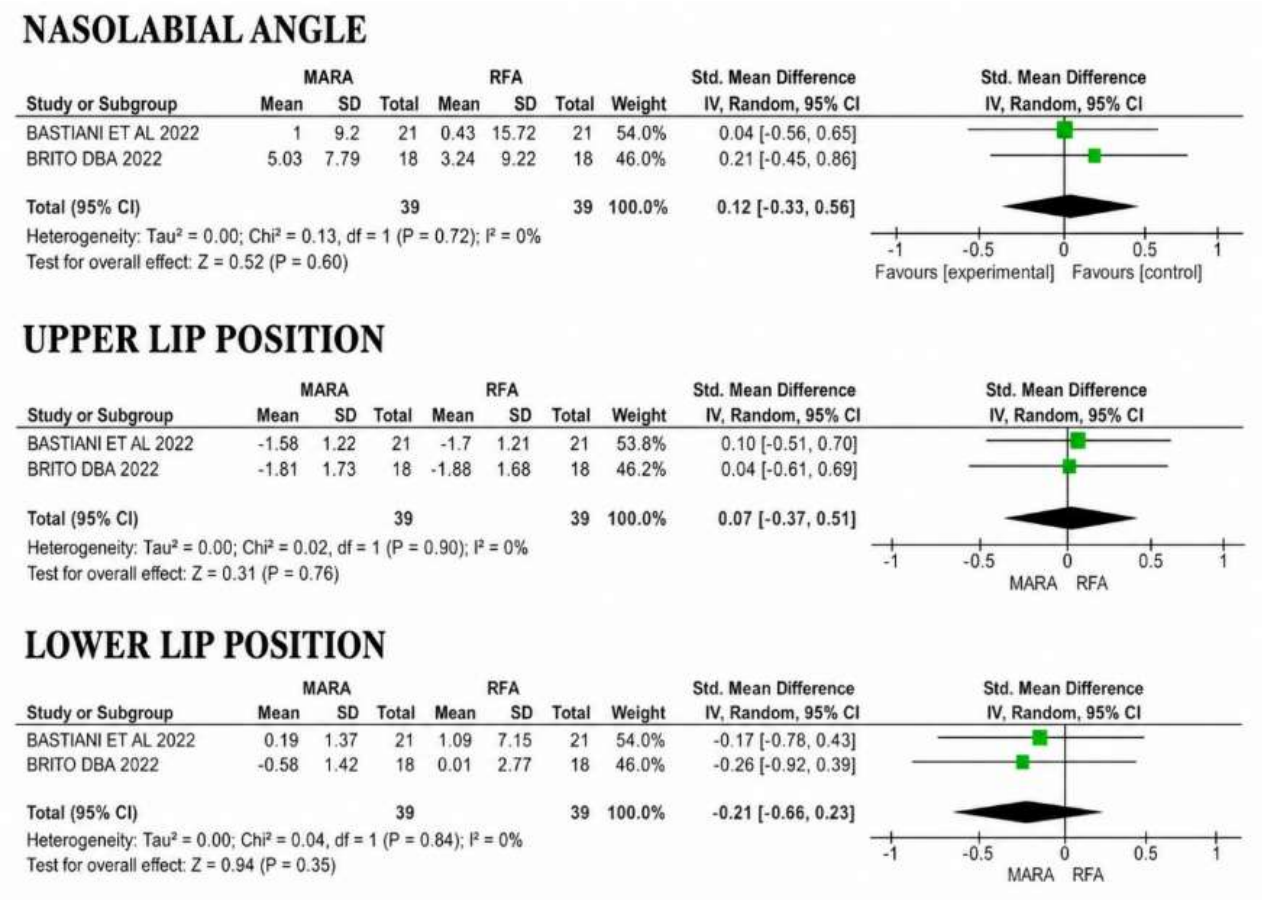


FIG 5a : MARA VERSUS FIXED FUNCTIONAL APPLIANCE (SKELETAL)

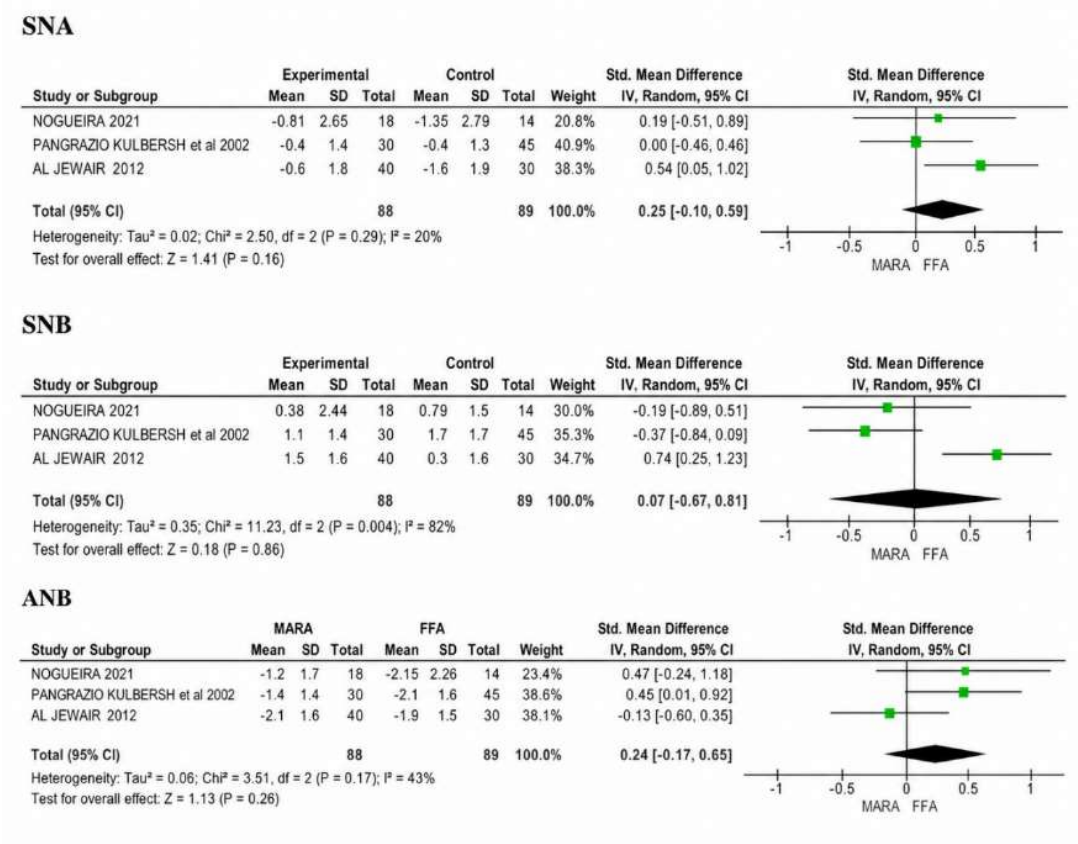


FIG 5b

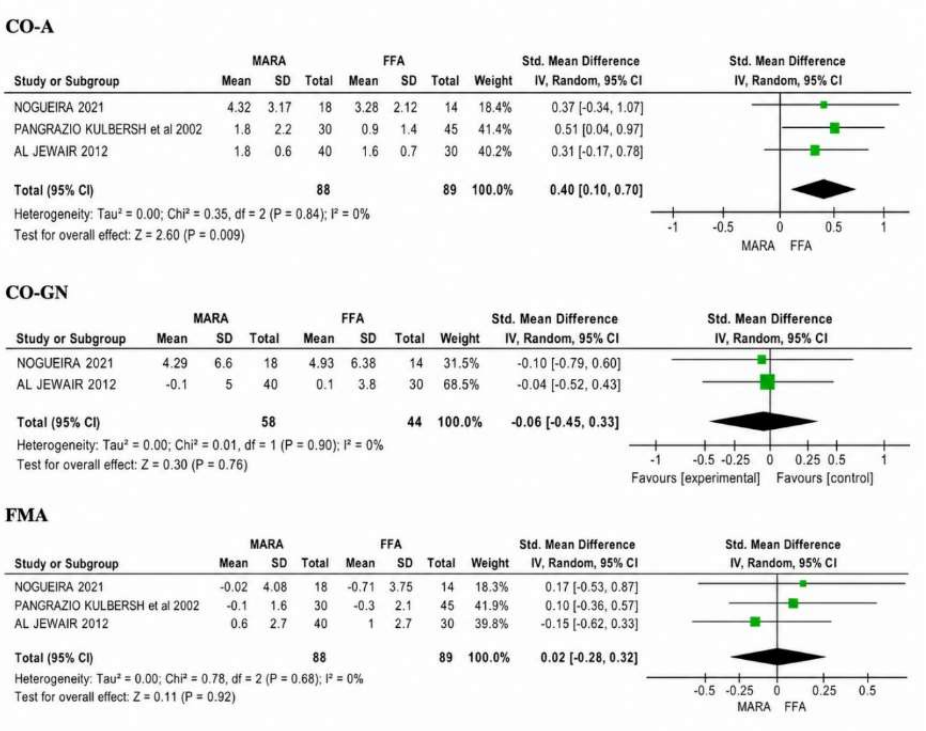
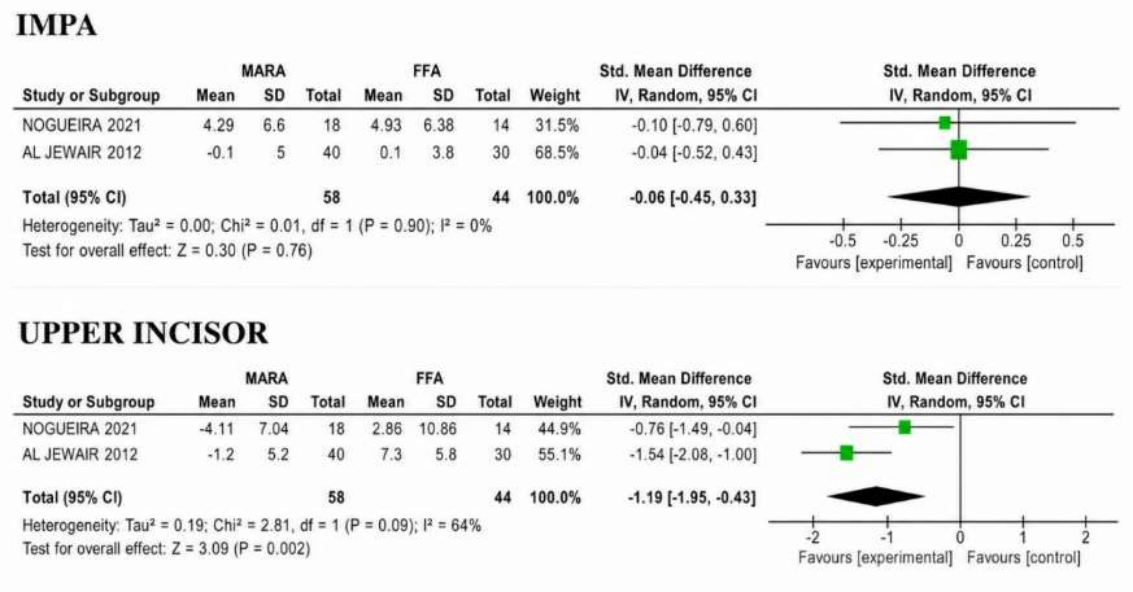


FIG 6 : MARA VERSUS FIXED FUNCTIONAL APPLIANCE (DENTAL)



TABLES

Table 1: Eligibility Criteria

	Inclusion criteria	Exclusion criteria
Population	**Patients with skeletal class II division I malocclusion with mandibular retrusion in the growth phase as assessed with the aid of skeletal maturity indicators.**	**Patients with skeletal class II division I malocclusion with mandibular retrusion whose growth phase has been completed.**
Intervention	**Mandibular anterior repositioning appliance**	
Comparator	**Compared with other Fixed and removable functional appliances.**	**Compared mara with untreated controls**
Outcome	**Skeletal, dental, soft tissue changes**	
Study design	**Randomized clinical trial, prospective studies, retrospective studies, cohort studies.**	**Case reports, case series, animal studies, in vitro studies, material studies, microbial assays, and clinical trials without control groups.**

Table 1: Eligibility Criteria

Table 2: Demographic Characteristics table

S. no	Study	Design	Setting	Characteristics of patients	Interventions	No. of patients (M/F)	Age in years (SD)	Skeletal growth stage	Treatment time	Outcomes

1.	**Brito DBA et al Dental Press J Orthod 2022**	**CCT retrospective longitudinal study**	**School of dentistry, Bauru**	**Bilateral Class II division 1 malocclusion (minimum severity of ½ cusp molar relationship), absence of agenesis, convex facial profile, and no previous history of orthodontic treatment, ANB angle greater than 4 degrees and overbite greater than 5 mm**	**<u>Group I- MARA</u> followed by multibracket fixed appliances Group II – Activator headgear followed by multibracket fixed appliances Group III- control group**	**<u>Overall - 56</u> Group I- 18 subjects (13 male, 5 female) Group II- 18 subjects (12 male, 6 female) Group III- 20 subjects (10 male, 10 female**	**<u>Group I-</u> 11.70 ± 1.11 years and 15.30 ± 1.20 years, Group II- 10.88 ± 0.80 years and 14.06 ± 1.35 years Group III- 11.07 ±0.50 years and 15.20 ±0.93 years**	**-**	**<u>Group I-</u> 3.60 ± 0.91 years Group II- 3.17 ± 1.50 years Group III- 4.13 ±1.15 years**	**Skeletal ,dental and soft tissue**
2.	**Pangrazio-kulbersh et al AJODO 2002**	**CCT,retrospective study**	**Department of Orthodontics, School of Dentistry, University of Detroit Mercy, Detroit, Michigan, USA**	**The patient exhibited continued growth, ANB angle was greater than 4.5°, the mandible was retrognathic, Class II with at least an end-to-end molar and canine relationship, landmarks were readily identifiabl**	**<u>Group I- MARA</u> Group II- CONTROL Group III- Frankel Group IV- Herbst**	**<u>Group I-30</u> 12 boys 18 girls GROUP II- Class II control subjects (13 girls and 8 boys)**	**<u>Group I-</u> boys (average age, 11.2 years; range, 9.5-15.8 years) and girls (average age, 11.3 years; range, 9.9-15.0 years) Group II-**	**Peak pubertal growth spurt**	**10.7 months (range, 8-17 months)**	**Skeletal and dental**

				e on the radiograph, the appliance was not removed prematurely due to breakage			**11.1 years Group III- 11.6 years Group IV- 12 years**			
3.	**Siara-Olds et al** **Angle Orthod** **2009**	**CCT, <u>Retrospective study</u>**	**Department of Orthodontics, University of Detroit Mercy**	**Class II division 1 malocclusions characterized by a retrognathic mandible (SNA- 80, SNB -76, and SN-GoGn - 35), CVM between stage 2 and 3 at initial records, landmarks were identifiable on all of the radiographs, treatment of functional appliance therapy was not combined with a headgear. All patients wore the functional appliances until full eruption of the permanent dentition, at which time the second**	**<u>GROUP I- Bionator</u> GROUP II- Herbst GROUP III- Twinblock GROUP IV- MARA GROUP V- Control**	**<u>GROUP I- 20</u> GROUP II- 20 GROUP III- 20 GROUP IV- 20 GROUP V- 21**	**<u>GROUP I-</u> 10 years 7 months (range, 8 years 7 months to 13 years 9 months) GROUP II- 12 years 2 months (range, 10 years 6 months to 14 years 1 month) GROUP III- 10 years 11 months (range, 8 years 2 months to**	**Peak pubertal growth spurt**	**<u>GROUP I-</u> 49.0 months GROUP II- 41.6 months GROUP III- 41.6 months GROUP IV- 43.7 months**	**Skeletal ,dental , softtissue**

				phase of fixed appliance treatment commenced			**13 years 9 months) GROUP IV- 11 years 1 month (range, 9 years 0 months to 14 years 4 months)**			
4.	**Al-Jewair et al Angle Orthod 2012**	**CCT,Retrospective study**	**Health sciences institutional research board of university at Buffalo**	**Class II malocclusion with the molars in at least an end-to-end relationship, presenting during the peak growth spurt as indicated by the improved version of the cervical vertebral maturation (CVM) method,8 retrognathic mandible (SNB 77), ANB angle 4, normal Frankfort to Mandibular plane angle (FMA 25**	**GROUP I-MARA GROUP II-Advansync GROUP III-control**	**GROUP I-40 GROUP II-30 GROUP III-24**	**GROUP I- T1-11.6 T2-13 T3-1.6 GROUP II-T1-12.3 T2-13.4 T3-14.7 GROUP III-T1-11.9 T2- 13 T3-14.4**	**Peak pubertal growth spurt**	**GROUP I- 3.3 ± 1.9 GROUP II- 2.3 ± 0.7 GROUP III- 3.0 ±1.0**	**Skeletal and dental changes**

				+_ 5), overjet ,10 mm, no missing teeth, a nonextraction treatment approach, crowns cemented on permanent maxillary and mandibular first molars, and the appliance maintained for at least 6 months						
5.	**Noguera et al** **AJODO 2021**	**CCT, Retrospective study**	**University of Sao Paulo**	**Class II dv I withbilateral molar relation,convex profile,overjet >5 mm**	**GROUP I-Forsus GRUP II-MARA GROUP III-control**	**GROUP I-14 GROUP II-18 GROUP III-14**	**GROUP I-12.4 6 1.3 years GROUP II-12.1 6 1.3 years GROUP III-11.54 6 0.61**	**-**	**_**	**Skeletal and dental changes**

6.	**Bastiani et al AJODO 2023**	**CCT, Retrospective study**	**University of Sao Paulo**	**Class II molar with cusp to cusp molar and canine relationMIN ANB – 3,no crowding, moderate or severe overjet**	**GROUP I- TWIN BLOCK GROUP II- MARA GROUP III- CONTROL**	**GROUP I- 21 GROUP II- 21 GROUP III- 24**	**GROUP I- initial and final ages of 10.59 and 11.97 years GROUP II- initial and final ages of 11.98 and 13.20 years GROUP III- initial and final ages of 10.55 and 12.01 years**	**-**	**GROUP I- 1.38 years GROUP II- 1.22 years GROUP III- 1.46 years**	**Skeletal ,softtissue and dental changes**

Table 3: Risk Of Bias

STUDIES	DOMAIN I	DOMAIN II	DOMAIN III	DOMAIN IV	DOMAIN V	DOMAIN VI	DOMAIN VII	OVERALL
BRITO DBA ET AL	VARIANT A-LOW VARIANT B-LOW	LOW	LOW	LOW	LOW	MODERATE	MODERATE	LOW TO MODERATE
PANGRAZIO-KULBERSH ET AL	VARIANT A-LOW VARIANT B-LOW	LOW	LOW	LOW	LOW	MODERATE	MODERATE	LOW TO MODERATE
SIARA-OLDS ET AL	VARIANT A-LOW VARIANT B-LOW	LOW	LOW	LOW	LOW	MODERATE	MODERATE	LOW TO MODERATE
AL JEWAIR ET A	VARIANT A-LOW	LOW	LOW	LOW	LOW	MODERATE	MODERATE	LOW TO MODERATE

	VARIANT B-SERIOUS							
NOGUERIA ET AL	**VARIANT A-LOW VARIANT B-SERIOUS**	**LOW**	**LOW**	**LOW**	**LOW**	**MODERATE**	**MODERATE**	**LOW TO MODERATE**

Table 4-Comparison of MARA with removable functional appliances (Pre – Post appliance therapy)

SKELETAL	BRITO DBA ET AL		PANGRAZIO KULBERSH ET AL		SIARA OLDS ET AL		
	MARA	ACHG	MARA	FRANKEL	MARA	BIONATOR	TWINBL
	MEAN DIFFERENCE		MEAN DIFFERENCE		MEAN DIFFERENCE		
SNA(°)	0.01 ± 2.49	-1.87 ± 2.18	-0.4 ± 1.4	-0.4 ± 0.7	-1.39	-0.48	-0.19
CO-A	2.28 ± 3.66	2.28 ± 2.93	NA	NA	1.75	0.98	1.50
SNB(°)	0.98 ± 2.13	0.55 ± 1.76	1.1 ± 1.4	0.6 ± 0.7	-0.43	0.43	0.83
CO-GN	7.79 ± 4.81	8.38 ± 2.94	4.8 ± 4.4	4.3 ± 1.3	4.25	3.84	4.78
ANB(°)	-0.99 ± 1.51	-2.43 ± 1.65	-1.4 ± 1.4	- 1.0 ± 0.7	-0.93	-0.92	-1.02
FMA(°)	-0.02 ± 2.20	0.60 ± 4.38	-0.1 ± 1.6	-0.4 ± 1.0	NA	NA	NA
DENTAL:	BRITO DBA ET AL		PANGRAZIO KULBERSH ET AL		SIARA OLDS ET AL		
	MARA	ACHG	MARA	FRANKEL	MARA	BIONATOR	TWINB
MX1-PP(°)	-3.34 ± 8.07	-4.19 ± 7.98	NA	NA	NA	NA	N
MX1-APO(°)	-2.97 ± 2.47	-2.39 ± 2.47	NA	NA	NA	NA	N
U1-FH(°)	NA	NA	NA	NA	1.07	-2.64	-0
MX1-NA(°)	NA	NA	NA	NA	NA	NA	N
U1-L1(°)	NA	NA	NA	NA	NA	NA	
MX1-PP(MM)	1.10 ± 1.77	1.61 ± 1.61	NA	NA	NA	NA	
U1-VERTICAL(MM)	NA	NA	NA	NA	NA	NA	
UI HORIZONTAL (MM)	NA	NA	NA	NA	NA	NA	
MX1-NA (MM)	NA	NA	NA	NA	NA	NA	
MD1-NB(°)	3.27 ± 6.54	4.07 ± 4.72	NA	NA	NA	NA	
MD1-MP(°)	2.08 ± 2.27	1.29 ± 1.83	NA	NA	NA	NA	
IMPA(°)	NA	NA	3.9 ± 3.2	NA	2.46	-0.53	
MD1-NB(MM)	1.02 ± 1.30	1.29 ± 1.83	NA	NA	NA	NA	
Lower incisor horizontal (mm)	NA	NA	0.6 ± 0.8	0.1 ± 1.1	NA	NA	
Lower incisor vertical (mm)	NA	NA	0.5 ± 1.7	0.6 ± 0.9	NA	NA	
L1-PT A POG(MM)	NA	NA	NA	NA	NA	NA	
MX6-PP(MM)	2.71 ± 1.09	2.11 ± 2.01	0.1 ± 2.9	NA	NA	NA	
MX6-A PERP(MM)	-0.84 ± 1.97	-1.12 ± 1.79	NA	NA	NA	NA	
UPPER Molar horizontal (mm)	NA	NA	-1.1 ± 2	0.7 ± 1.1	NA	NA	

SOFT TISSUE: RESEARCH PAPER	BRITO DBA ET AL		PANGRAZIO KULBERSH ET AL			BASTIAN ET AL	
	MARA	ACHG	MARA	BIONATOR	TB	MARA	TW
	MEAN DIFFERENCE		MEAN DIFFERENCE			MEAN DIFFEREN	
NASOLABIAL ANGLE(°)	5.03 ± 7.79	3.24 ± 9.22	-1.15	-2.47	0.41	1.00 ± 9.20	0.43 ±
UPPER LIP(mm)	-1.81 ± 1.73	-1.88 ± 1.68	-0.27	-0.29	-0.53	-1.58 ± 1.22	-1.70
LOWER LIP(mm)	-0.58 ± 1.42	0.01 ± 2.77	0.39	0.16	0.02	0.19 ± 1.37	1.09
UPPER Molar vertical (mm)	NA	NA	1.6 ± 2.3	1.6 ± 1.0	NA	NA	
MD6-MP(MM)	3.10 ± 1.94	2.47 ± 1.33	NA	NA	NA	NA	
MD6-PG PERP(MM)	2.47 ± 1.33	0.26 ± 2.21	NA	NA	NA	NA	
Lower molar horizontal (mm)	NA	NA	1.2 ± 1.3	0.1 ± 0.7	NA	NA	
Lower molar vertical (mm)	NA	NA	1.3 ± 1.6	1.7 ± 0.9	NA	NA	

Table 5-Comparison of MARA with fixed functional appliances (T2-T1):(Pre – Post appliance therapy)

SKELETAL	**PANGRAZIO KULBERSH ET AL**		**SIARA OLDS ET AL**		**AL JEWAIR ET AL**	**NOGUERIA ET AL**
	MARA	**HERBST**	**MARA**	**HERBST**	**MARA ADVANSYNC**	**MARA FORSUS**
	MEAN DIFFERENCE		**MEAN DIFFERENCE**		**MEAN DIFFERENCE**	**MEAN DIFFERENCE**
SNA(°)	**-0.4 ± 1.4**	**-0.4 ± 1.3**	**-1.39**	**-0.59**	**-0.5 ± 6 1.5** **-1.6 ± 6 2.4**	**-0.81 ±2.65** **-1.35 ±2.79**
CO-A(mm)	**NA**	**NA**	**1.75**	**0.13**	**1.8 ± 0.6** **1.0 ± 0.7**	**4.32 ± 3.17** **3.28 ± 2.12**
SNB(°)	**1.1 ± 1.4**	**1.7 ± 1.7**	**-0.43**	**0.56**	**1.5 ± 1.6** **0.3 ± 1.6**	**0.38 ±2.44** **0.79 ± 1.50**
CO-GN(mm)	**4.8 ± 4.4**	**4.8 ± 2.3**	**NA**	**NA**	**4.5 ± 3.6** **4.0 ± 2.4**	**9.11 ± 4.33** **7.90 ± 3.26**
ANB(°)	**-1.4 ± 1.4**	**-2.1 ± 1.6**	**NA**	**NA**	**-2.1 ± 1.6** **-1.9 ± 1.5**	**-1.2 ± 1.70** **-2.15 ± 2.26**
FMA(°)	**-0.1 ± 1.6**	**-0.3 ± 2.1**	**NA**	**NA**	**0.6 ± 2.7** **1.0 ± 2.7**	**-0.02 ± 4.08** **-0.71 ± 3.75**
DENTAL:	**PANGRAZIO KULBERSH ET AL**		**SIARA OLDS ET AL**		**AL JEWAIR ET AL**	**NOGUERIA ET AL**
	MARA	**HERBST**	**MARA**	**HERBST**	**MARA ADVANSYNC**	**MARA FORSUS**

MX1-PP(°)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**-4.11 ± 7.04 ± 10.8**	**2.86**
MX1-APO(°)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**-2.95 ± 2.2 ± 1.94**	**-0.30**
U1-FH(°)	**NA**	**NA**	**1.07**	**-1.95**	**2.3 ± 9.4 ± 4.7**	**-8.4**	**NA**	**NA**
MX1-NA(°)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
U1-L1(°)	**NA**	**NA**	**NA**	**NA**	**-8.4 ± 10.5 ± 2.3**	**2.1**	**NA**	**NA**
MX1-PP(MM)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**1.72 ± 3.01 ± 1.76**	**1.87**
U1-VERTICAL(MM)	**NA**	**NA**	**NA**	**NA**	**0.2 ± 2.1 ± 1.7**	**0.3**	**NA**	**NA**
UI HORIZONTAL(MM)	**NA**	**NA**	**NA**	**NA**	**2.3 ± 9.0 ± 3.1**	**-1.8**	**NA**	**NA**
MX1-NA(MM)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
MD1-NB(°)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**4.51 ± 5.78 ± 6.30**	**4.9**
MD1-MP(°)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**1.97 ± 3.70 ± 2.10**	**1.11**
IMPA(°)	**3.9 ± 3.2**	**NA**	**2.46**	**0.32**	**5.4 ± 5.9 ± 3.6**	**5.3**	**4.29± 6.60 ± 6.38**	**4.93**
MD1-NB(MM)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**1.04 ± 1.73 ± 1.60**	**1.69**
Lower incisor horizontal (mm)	**0.6 ± 0.8**	**1.6 ± 3.2**	**NA**	**NA**	**1.7 ± 6.3 ± 2.4**	**1.1**	**NA**	**NA**
Lower incisor vertical (mm)	**0.5 ± 1.7**	**-1.1 ± 1.6**	**NA**	**NA**	**0.0 ± 5.2 ± 1.9**	**0.2**	**NA**	**NA**
L1-PT APOG(MM)	**NA**	**NA**	**NA**	**NA**	**3.1 ± 2.3 ± 1.5**	**2.6**	**NA**	**NA**
MX6-PP(MM)	**0.1 ± 2.9**	**NA**	**NA**	**NA**	**NA**	**NA**	**3.67 ± 2.80 ± 2.47**	**2.11**
MX6-APERP(MM)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**-0.11 ± 3.38 ± 4.85**	**-1.54**
UPPER Molar horizontal (mm)	**-1.1 ± 2 1.9**	**-1.4 ±**	**NA**	**NA**	**0.7 ± 2.8 ± 2.7**	**-0.5**	**NA**	**NA**
UPPER Molar vertical (mm)	**1.6 ± 2.3 1.3**	**0.5 ±**	**NA**	**NA**	**0.9 ± 2.0 ± 1.5**	**0.1**	**NA**	**NA**
MD6-MP(MM)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**3.71 ± 2.64 ± 2.70**	**3.78**
MD6-PGPERP(MM)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**-0.60 ± 3.37 ± 5.57**	**-1.34**

Lower molar horizontal (mm)	**1.2 ± 1.3**	**1.4 ± 1.3**	**NA**	**NA**	**3.0 ± 2.5**	**2.8 ± 2.2**	**NA**	**NA**
Lower molar vertical (mm)	**1.3 ± 1.6**	**1.3 ± 1.5**	**NA**	**NA**	**2.2 ± 5.3**	**2.4 ± 1.7**	**NA**	**NA**
SOFT TISSUE:	**PANGRAZIO KULBERSH ET AL**		**SIARA OLDS ET AL**		**AL JEWAIR ET AL**		**NOGUERIA ET AL**	
	MARA HERBST		**MARA HERBST**		**MARA ADVANSYNC**		**MARA FORSUS**	
	MEAN DIFFERENCE		**MEAN DIFFERENCE**		**MEAN DIFFERENCE**		**MEAN DIFFERENCE**	
NASOLABIAL ANGLE(°)	**NA**	**NA**	**-1.15**	**1.62**	**NA**	**NA**	**3.29 ± 8.19**	**0.65 ± 7.64**
UPPER LIP(mm)	**NA**	**NA**	**-0.27**	**-0.98**	**NA**	**NA**	**-2.91 ± 1.69**	**-1.3 ± 0.96**
LOWER LIP(mm)	**NA**	**NA**	**0.39**	**-0.20**	**NA**	**NA**	**-1.32 ± 1.94**	**0.72 ± 1.84**

Supplementary table 1 : Search strategy in different electronic database

DATABASE	SEARCH STRATEGY USED	NO . OF STUDIES
PubMed	**((((mandibular anterior repositioning appliance) OR (mara)) AND (removable functional appliance)) OR (fixed functional appliance)) AND (class II Malocclusion)**	**1109**
SCOPUS	**(TITLE-ABS-KEY (mandibular anterior repositioning appliance) OR TITLE-ABS-KEY (MARA) AND TITLE-ABS-KEY (removable functional appliance) OR TITLE-ABS-KEY (fIXED functional appliance) AND TITLE-ABS-KEY (CLASS II MALOCCLUSION))**	**21**
Cochrane library	**mandibular anterior repositioning appliance in Title Abstract Keyword OR MARA in Title Abstract Keyword AND removable functional appliance in Title Abstract Keyword OR fixed functional appliance in Title Abstract Keyword AND class II Malocclusion in Title Abstract Keyword**	**122**
Web of science	**((((ALL=(mandibular anterior repositioning appliance)) OR ALL=(mara)) AND ALL=(fIXED functional appliance)) OR ALL=(removable functional appliance)) AND ALL=(class II malocclusion)**	**139**
Lilac	**(mandibular anterior repositioning appliance) OR**	**4**

	(MARA) AND (removable functional appliance) OR (fixed functional appliance) AND (class II Malocclusion)	