Systematic Review Article

Meta-analysis on the mandibular dimensions effects of the MARA appliance in patients with Class II malocclusions

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ABSTRACT

Objectives: To evaluate the short- and long-term effects of the mandibular anterior repositioning appliance (MARA) on mandibular dimensions in patients with Class II malocclusion and to assess the stability of the MARA results.

Materials and Methods: Multiple electronic databases were searched for articles published in any language until March 2014. A manual search was also performed of reference lists of retrieved articles. The primary outcomes were the short-and long-term effects of the MARA appliance on mandible dimensions. The secondary outcome was postretention stability. Outcome measures were total mandibular unit length, corpus length, and ramus height. Two reviewers examined all articles independently and assessed their methodologic quality. Meta-analyses were conducted using random-effects models. The Cochrane test and the I^2 statistic were used to assess heterogeneity. Sensitivity analyses were performed and publication bias was evaluated.

Results: Seven retrospective clinical controlled studies that compared MARA with controls were included. Three of the studies were medium quality; the rest were low quality. Meta-analysis of the short-term effects revealed a significant increase in total mandibular unit length (1.16 mm/y) and ramus height (1.58 mm/y) with MARA and a nonsignificant increase in corpus length (0.21 mm/y). Analyses of the long-term effects showed a statistically significant advantage of MARA over controls for all three variables, but the effect sizes were small. More high-quality studies are warranted.

Conclusions: The MARA appliance produced statistically significant mandibular growth enhancement in the short- and long-term. These findings, however, may not be clinically significant. (*Angle Orthod.* 2015;85:706–714.)

KEY WORDS: Cephalometry; Mandibular growth; Orthodontic appliances; Malocclusion

INTRODUCTION

Class II malocclusion is a prevalent form of orthodontic discrepancy that is commonly associated with mandibular retrognathia.[1] A number of functional appliances are available to treat Class II malocclusions in growing subjects. Some are removable and others are fixed.[2,3] The goal of most of these appliances is to stimulate mandibular growth by posturing the mandible forward into a Class I occlusion. The expectation is that the condylar processes will remodel superiorly and posteriorly in the condylar fossae.[2]

One of the many functional appliances available today is the mandibular anterior repositioning appliance (MARA). This appliance corrects a Class II malocclusion into a Class I by displacing the mandibular condyles anteriorly and inferiorly, thereby resulting in remodeling of the temporal fossae and the condyles.[4]

The efficacy of the MARA on mandibular growth has been evaluated in numerous studies, but contradictory results have been reported.[5–7] Some studies found significant mandibular dimensional changes with MARA,[6,8] whereas others found no significant differences between MARA and untreated control subjects with Class II malocclusion.[5,9] Therefore, the objective of this review was to evaluate the short- and long-term effects of the MARA appliance on mandibular dimensions in growing patients (10–16 years old) and to assess the postretention stability of the MARA results.

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Accepted: July 2014. Submitted: May 2014.
Published Online: September 2, 2014

 DOI: 10.2319/052814-378.1

Table 1. Inclusion/Exclusion Criteria for Studies Using a Mandibular Anterior Repositioning Appliance (MARA)

Population	Intervention	Control	Outcomes	Types of Studies
– Adolescent boys and girls (10–16 years old) – Class II malocclusion with molars in at least an end-to-end relationship – Retrognathic mandible – Lateral cephalograms taken	– Insertion of MARA appliance followed by upper and lower fixed orthodontic appliances	– Untreated matched subjects – Historical controls	– Short- and long-term mandibular growth effects including: ▪ Total mandibular unit length using Co-Gn, Co-Pg, or Pg/Olp + Co/Olp ▪ Corpus length using Go-Gn, Go-Me, or Go-Pg ▪ Ramus height using Co-Go – Postretention stability of MARA results	– Randomized controlled trials – Prospective and retrospective controlled clinical trials

MATERIALS AND METHODS

Study Inclusion/Exclusion Criteria

The PICO (patient, problem, or population; intervention; comparison; outcome) criteria were used to determine whether a study should be included or excluded (Table 1). Studies considered for inclusion were randomized controlled trials (RCTs), prospective controlled clinical trials, and retrospective controlled clinical trials on humans with no restriction on the sample size. Case reports, case series, review articles, editorials, and commentaries were all excluded. The primary outcomes were the short-term (measured after removal of the MARA functional appliance) and the long-term (measured after the completion of the comprehensive fixed orthodontic treatment) effects of the MARA on the mandibular dimensions. The secondary outcome was the postretention stability of the changes obtained with the MARA (measured at least 1 year postretention). Outcome measures were total mandibular unit length, corpus length, and ramus height. Only studies that used the cephalometric landmark condylion were included. Studies were excluded if the measurements used the constructed point articulare.

Data Sources

Multiple electronic databases were searched for articles published in any language until March 2014, including Ovid MEDLINE, EMBASE, Database of Abstracts of Reviews of Effectiveness (DARE), Educational Resources Information Center (ERIC), Cumulative Index to Nursing & Allied Health (CINAHL), Cochrane Controlled Trials Register, Cochrane Database of Systematic Reviews, PubMed, and the World Wide Web using Google Scholar. The System for Information on Grey Literature in Europe (SIGLE) was searched for grey literature. Medical subject headings (MeSH) or text words were used depending on the database (Table 2). A manual search was also performed of theses and dissertations as well as reference lists of retrieved articles. Two reviewers carried out the search for the studies independently and in duplicate. Full articles underwent quality assessment. Disagreements were resolved through discussion.

All articles were reviewed, and data were extracted using a customized data abstraction sheet. The quality of the studies was independently assessed using the Cochrane collaboration's tool for assessing risk of bias.[10] The criteria for the assessment were (1) random sequence generation, (2) allocation concealment, (3) blinding of outcome assessors (blinding of participants was not possible), (4) completeness of outcome data, (5) evaluation of selective reporting, and (6) no other sources of bias. The possible responses for each criterion were yes, unclear, or no. For this study, the score categories were two points for

Table 2. Search Strategy for Included Articles[a]

Key Words	Category	Electronic and Nonelectronic Search Results
MARA or mandibular anterior repositioning appliance or mandibular advancement repositioning appliance	MARA	2482
Class II malocclusions or Class II division 1 malocclusions or malocclusions	Class II malocclusion	7373
	Combination	9855
	Removal of duplicates	37
	Inclusion at the title stage	31
	Inclusion at the abstract stage	25
	Full review	10
	Included articles	7

"yes," one point for "unclear," and no point for "no." The quality of the studies was considered low if it received 1–4 points, medium if it received 5–8 points, or high if it received 9–12 points. Disagreement was resolved through discussion.

Statistical Analysis

Meta-analyses were conducted for the continuous outcomes assessed in the studies. The sample size, the mean difference (MD), and standard deviation of the difference (SD diff) of the changes in total mandibular unit length, corpus length, and ramus height were all obtained for MARA and controls from each study. Two studies[5,9] did not report the standard deviations of the mean changes; thus, they were estimated on the basis of the MD, sample size, and *P* values as explained in the *Cochrane Handbook for Systematic Reviews of Interventions*.[10]

Review Manager software, version 5.2 was used to analyze the data.[11] The statistical effect size was calculated using weighted MD (WMD) and 95% confidence Interval (CI); studies were combined using the inverse variance random-effects models method. Effect size was considered significant if $P < .05$. Heterogeneity between the studies was assessed using the Cochrane test ($P < .1$ was considered significant) and the I^2 statistic.[12] An I^2 cutoff of 25%, 50%, and 75% was used to represent low, moderate, and high heterogeneity, respectively.[12,13] Sensitivity analyses were performed to assess the robustness of the meta-analyses based on study quality, sample size, and matching by skeletal maturational age. Publication bias was assessed using the Egger's linear regression,[14] using the Begg and Mazumdar[15] rank correlation, and by visually checking the symmetry of the funnel plots. A symmetrical funnel plot and nonsignificant two-tailed Egger's and Begg's tests indicate no publication bias.

RESULTS

The search identified 37 relevant articles. After exclusion at the title and abstract stages, 10 studies underwent qualitative assessment. Three were excluded because one was not available,[16] one did not use the landmark condylion,[17] and one used a dissimilar follow-up period for the MARA and controls.[18]

Therefore, only seven retrospective clinical controlled studies met the inclusion criteria.[5,6,8,9,19–21] The participants were growing subjects with Class II division 1 malocclusion in all studies except for one in which the type of Class II malocclusion was not specified.[6] The age ranges were 10.11–12.3 years for the MARA subjects (N = 180) and 11.63–11.9 years for the control subjects (N = 126). One study[20] did not specify the age range or the sample size for the control group. Descriptions of the included studies are presented in Table 3.

One of the studies evaluated the effects of treatment timing with MARA and fixed appliances in patients with Class II malocclusions compared with untreated historical controls.[20] They evaluated patients at the prepubertal, pubertal and postpubertal skeletal developmental stages before treatment (T1) and after comprehensive treatment (T2). For the purpose of this meta-analysis, only the group treated during the peak growth spurt was included. Four other studies[5,8,9,21] included subjects who were treated at the beginning of or during the growth spurt.

Outcomes assessed were the short- and long-term effects of MARA on mandibular dimensions (Table 4). Outcome measures included the mean changes in total mandibular unit length using Co-Gn; corpus length using Go-Gn, Go-Me, and Go-Pg; and ramus height using Co-Go. No studies were found for the postretention stability outcome. Overall mean treatment duration ranged from 10.7 to 18 months for MARA and from 27 to 54 months for the total comprehensive orthodontic treatment/observation period. The MARA treatment protocols reported in the studies included MARA alone, MARA with concurrent 2 × 4 fixed appliances, or MARA with full upper and lower fixed orthodontic appliances bonded at the start of the treatment.

Three of the studies[8,9,21] were medium quality; the rest were low quality. Data from all the studies were used in the quantitative analyses of the short- and long-term effects on mandibular dimensions. All values were annualized to account for the different mean treatment times.

Short-Term Effects of MARA

Changes in total mandibular unit length. Six studies[5,6,8,9,19,21] evaluated this outcome using the cephalometric variable Co-Gn. The meta-analysis showed a 1.16 mm/y increase in the total mandibular length of the MARA group over controls (WMD = 1.16; 95% CI = 0.61, 1.72; χ^2 test = 7.32; 5 *df*; $P = .20$; $I^2 = 32\%$; test for overall effect, Z = 4.11 and $P \leq .0001$) (Figure 1). Sensitivity analysis excluding the three low-quality studies[5,6,19] showed comparable findings (WMD = 1.12; 95% CI = 0.60, 1.63) (Table 5).

Changes in mandibular corpus length. Different cephalometric variables were used among the studies. Two of them used Go-Me[5] and Go-Po,[6] respectively; the other two studies[8,9] used Go-Gn. Statistical pooling of the four studies showed no significant differences between the groups and a medium heterogeneity (WMD = 0.21; 95% CI = −0.16, 0.57; χ^2 test = 9.73; 3

Table 3. Summary of Studies That Met the Inclusion Criteria[a]

Authors and Year	Origin	No. of MARA Subjects	Initial Mean ± SD Age of MARA Subjects (y)	No. and Type of Untreated Control Subjects	Initial Mean ± SD Age of Control Subjects (y)	Mean Treatment Time With MARA	Total Treatment/ Observation Time (mo)	Outcome Measures	Quality[b]
Chiqueto et al.,[19] 2013	Brazil	22 F/M ratio: 7/15	11.99 ± 1.20	22 untreated subjects F/M ratio: 7/15	11.63 ± 1.03	12	-	Short-term effects (Co-Gn)	Low
Ghislanzoni et al.,[20] 2013	Italy	15 treated during peak growth spurt	11.4 ± 1.6	Historical controls (number not specified) Matched by skeletal maturation, dentoskeletal features, and age	Not specified	16 ± 7	27 ± 9	Long-term effects (Co-Gn)	Low
Al-Jewair et al.,[8] 2012	USA	40 F/M ratio: 18/22	11.6 ± 1.9	24 historical controls F/M ratio: 11/13 Matched by skeletal age, sex, and craniofacial morphology	11.9 ± 1.9	18 ± 9	39 ± 21	Short-term effects (Co-Gn, Go-Gn, Co-Go) Long-term effects (Co-Gn, Go-Gn, Co-Go)	Medium
Pangrazio et al.,[9] 2012	USA	30 F/M ratio: 18/12	11.9 for males 10.8 for females	21 historical controls Matched by skeletal age and skeletal characteristics	Not specified	15 ± 6	41 ± 6	Short-term effects (Co-Gn, Go-Gn, Co-Go) Long-term effects (Co-Gn, Go-Gn, Co-Go)	Medium
Ghislanzoni et al.,[21] 2011	Italy	23	10.2 ± 1.5	17 historical controls Matched by sex distribution, age, skeletal maturation, and dentoskeletal characteristics	11.63 ± 1.03	14 ± 5	54 ± 24	Short-term effects (Co-Gn, Co-Go) Long-term effects (Co-Gn, Co-Go)	Medium
Siara-Olds et al.,[5] 2010	USA	20	11.1	21 historical controls F/M ratio: 11/13 Matched by skeletal maturation	11.9 ± 1.9	18.7	42	Short-term effects (Co-Gn, Go-Me, Co-Go) Long-term effects (Co-Gn, Go-Me, Co-Go)	Low
Pangrazio-Kulbersh et al.,[6] 2003	USA	30 F/M ratio: 18/12	11.2 for males 11.3 for females	21 historical controls F/M ratio: 13/8 Matched by age and dentoskeletal characteristics	11.1	10.7	-	Short-term effects (Co-Gn, Go-Po, Co-Go)	Low

[a] MARA indicates mandibular anterior repositioning appliance; F, female; M, male; SD, standard deviation.

[b] Quality was defined as low (score of 1–4), medium (score of 5–8), or high (score of 9–12). Score categories: 2 points for "yes," 1 point for "unclear," and zero point for "no."

df; $P = .02$; $I^2 = 69\%$; test for overall effect, $Z = 1.11$ and $P = 0.27$). Analysis of the two studies[8,9] that used the same cephalometric measurements showed a similar effect size.

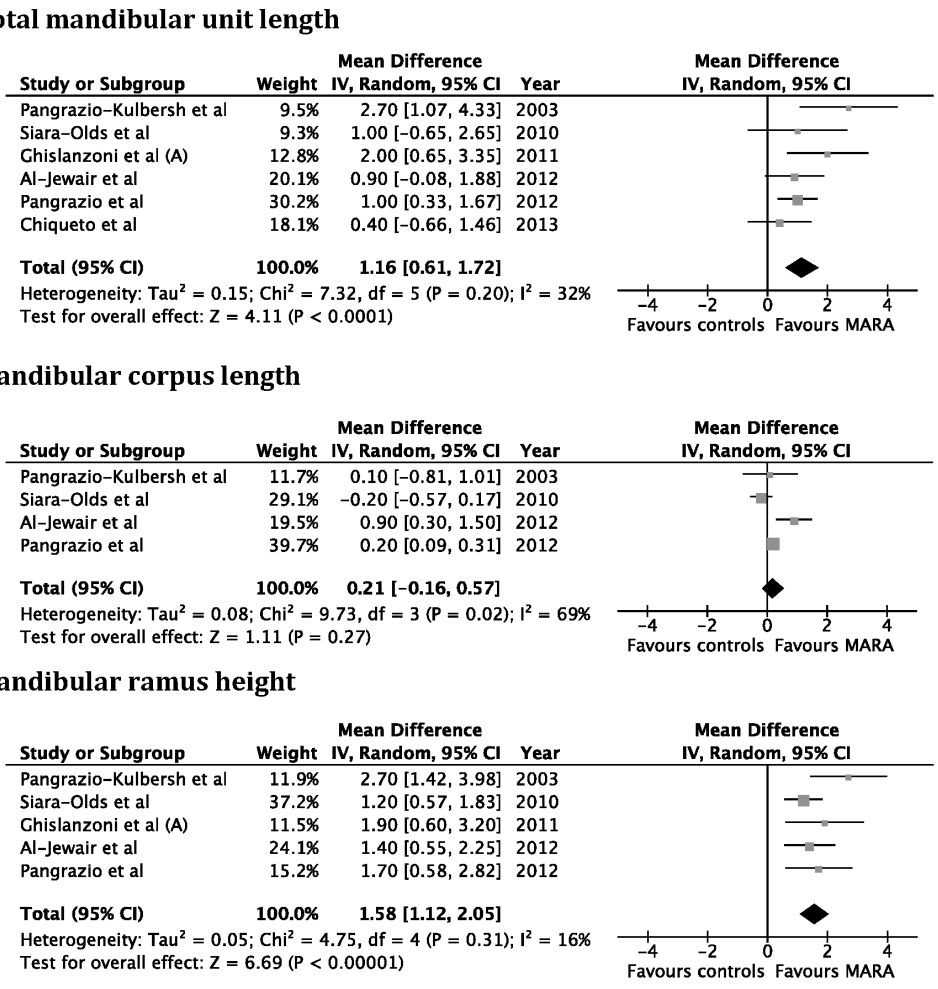
Changes in mandibular ramus height. Five studies[5,6,8,9,21] assessed the MD in the ramus height between MARA and controls using Co-Go. The difference was statistically significant favoring MARA (WMD = 1.58; 95% CI = 1.12, 2.05; χ^2 test = 4.75; 4 *df*; $P = .31$; $I^2 = 16\%$; test for overall effect, $Z = 6.69$ and $P \leq .0001$). A similar finding was observed after excluding two low-quality studies[5,6] (WMD = 1.59; 95% CI = 0.99, 2.19).

Evidence of publication bias was only noted for the ramus height outcome measure. The funnel plot was asymmetrical, and the Egger's and Begg's tests were statistically significant ($P = .018$ and $P = .03$, respectively). The Trim and Fill method was used to

Table 4. Annualized Short- and Long-Term Mandibular Dimensions Measurements in Millimeters[a]

		Mean Total Mandibular Unit Length			Mean Mandibular Corpus Length			Mean Mandibular Ramus Height		
	Authors	Cephalometric Measurement	MARA	Controls	Cephalometric Measurement	MARA	Controls	Cephalometric Measurement	MARA	Controls
Short-term	Chiqueto et al.,[19] 2013	Co-Gn	4.2	3.8	-	-	-	-	-	-
	Al-Jewair et al.,[8] 2012	Co-Gn	3.0	2.1	Go-Gn	2.2	1.3	Co-Go	2.9	1.5
	Pangrazio et al.,[9] 2012	Co-Gn	4.6	3.6	Go-Gn	2.6	2.4	Co-Go	2.7	1.0
	Ghislanzoni et al.,[21] 2011	Co-Gn	6.2	4.2	-	-	-	Co-Go	4.6	2.7
	Siara-Olds et al.,[5] 2010	Co-Gn	4.3	3.3	Go-Me	2.0	2.2	Co-Go	2.4	2.0
	Pangrazio-Kulbersh et al.,[5] 2003	Co-Gn	4.8	2.1	Go-Pg	1.7	1.6	Co-Go	4.0	1.3
Long-term	Ghislanzoni et al.,[20] 2013	Co-Gn	3.8	2.7	-	-	-	-	-	-
	Al-Jewair et al.,[8] 2012	Co-Gn	2.5	1.8	Go-Gn	1.7	0.9	Co-Go	2.4	1.2
	Pangrazio et al.,[9] 2012	Co-Gn	2.5	1.9	Go-Gn	2.3	1.4	Co-Go	1.4	0.3
	Ghislanzoni et al.,[21] 2011	Co-Gn	2.6	2.1	-	-	-	Co-Go	1.8	1.4
	Siara-Olds et al.,[5] 2010	Co-Gn	3.1	2.1	Go-Me	1.4	1.2	Co-Go	1.9	1.1

[a] MARA indicates mandibular anterior repositioning appliance.



[a] The forest plot consists of a vertical axis that crosses the horizontal axis at the point of zero where no mean difference in effectiveness between MARA and controls can be observed. The size of the square determines the weight each study contributes to the meta-analysis. It is calculated based on the inverse of variance. Horizontal line across the point estimate represents 95 percent confidence interval [CI] for each study. If the 95 percent CI crosses the vertical axis, a statistically non-significant difference between the groups is detected. The weighted mean difference of combined results is reported in the diamond. The center of the diamond is the point estimate, and the horizontal extension is its 95 percent CI.

Figure 1. Forest plots of MARA vs controls for the short-term mandibular dimensions outcome.

Table 5. Sensitivity and Subgroup Analyses for Short-Term Mandibular Dimensions Outcome for the MARA vs Control Groups[a]

Outcome	Original Pooled Estimate (95% CI) (mm/y)	Exclusion of Low-Quality Studies (mm/y)	*P* Value for Heterogeneity	Exclusion for Not Matching by Skeletal Maturation[b] (mm/year)	*P* value for Heterogeneity	Exclusion Due to Different/Unclear Skeletal Baseline Features (mm/year)	*P* Value for Heterogeneity
Total mandibular unit length	1.16 (0.61, 1.72)	1.12 (0.60, 1.63)	0.38	0.98 (0.54, 1.43)	0.50	0.86 (0.39, 1.33)	0.82
Mandibular corpus length	0.21 (−0.16, 0.57)	0.48 (−0.19, 1.16)	0.02	0.23 (−0.20, 0.66)	0.008	0.23 (−0.20, 0.66)	0.008
Mandibular ramus height	1.58 (1.12, 2.05)	1.59 (0.99, 2.19)	0.80	1.41 (0.97, 1.84)	0.75	1.35 (0.88, 1.81)	0.74

[a] MARA indicates mandibular anterior repositioning appliance; CI,s confidence interval.
[b] Studies were excluded if the MARA and control groups were not matched by skeletal maturation at baseline.

trim two studies to obtain symmetry in the funnel plot and the Random effect estimate was reduced to 1.37 (95% CI = 0.89, 1.83).

Long-Term Effects of MARA

Changes in total mandibular unit length. This outcome was assessed in five studies.[5,8,9,20,21] The MARA produced a statistically significant increase in the total mandibular length (WMD = 0.83; 95% CI = 0.59, 1.07; χ^2 test = 4.24; 4 *df*; $P = .34$; $I^2 = 6\%$; test for overall effect, Z = 6.75 and $P \leq .0001$) (Figure 2). A similar result was revealed when one low-quality study[5] and one medium-quality study with a small sample size[20] were excluded from the analysis (WMD = 0.59; 95% CI = 0.34, 0.83) (Table 6).

Changes in mandibular corpus length. This outcome was evaluated in three studies[5,8,9] that used different cephalometric measurements. The analysis showed a small advantage of MARA over controls (WMD = 0.61; 95% CI = 0.16, 1.06; χ^2 test = 6.62; 2 *df*; $P = .04$; $I^2 = 70\%$; test for overall effect, Z = 2.65 and $P = .008$). Sensitivity analysis using two studies[8,9] revealed similar findings (WMD = 0.82; 95% CI = 0.52, 1.12).

Changes in mandibular ramus height. Four studies[5,8,9,21] assessed the ramus height, and a 0.7 mm/y difference was detected (WMD = 0.70; 95% CI = 0.30, 1.11; χ^2 test = 3.37; 3 *df*; $P = .34$; $I^2 = 11\%$; test for overall effect, Z = 3.40 and $P = .0007$). Sensitivity analysis excluding one[5] study revealed a 0.76 mm/y difference (WMD = 0.76; 95% CI = 0.22,1.31).

No evidence of publication bias was detected for any of the long-term mandibular growth outcome measures.

DISCUSSION

The aims of this review were to evaluate the short- and long-term effects of MARA on mandibular dimensions in patients with Class II malocclusions and to assess the postretention stability of the MARA results.

All the studies that met the inclusion criteria were of low or medium quality. In several studies, the sample was not randomly selected or the random selection method was unclear. Only one study[19] used a concurrent untreated control group; the rest used historical controls. Historical controls might not be similar to the MARA group in the growth pattern. Although five studies[5,8,9,20,21] matched the MARA and control subjects by the cervical vertebral maturational age, two studies[6,19] used only chronological age and dentoskeletal characteristics to match the samples. All but three of the studies reported similar baseline skeletal features among the MARA and the control samples. One[6] reported a significant difference in the mean total mandibular unit length between the study groups, but the other two[20 21] did not discuss the results of the baseline cephalometric measurements.

Short-Term Effects of MARA

This review found a total mandibular length increase of 1.16 mm/y with MARA compared with control subjects with untreated Class II malocclusion. The effect size was sustained (1.11 mm/y) when two low-quality studies[6,19] were excluded and the associated heterogeneity was eliminated, which confirms a functional orthopedic effect of this appliance. A previous meta-analysis[22] evaluated the effectiveness of functional appliances on mandibular growth in the short term. In that study, 32 RCTs fulfilled the inclusion criteria for the review, but only four were selected for the quantitative analysis. Annualized results using the random-effect model revealed statistically significant mandibular growth of 1.79 mm over untreated control subjects. The high quality of studies included in the previous meta-analysis may explain the 65% difference in the increase of total mandibular length between the reviews.

Johnston[23] reported that nearly 4 to 6 mm of molar correction is needed to treat a Class II malocclusion. Thus, the 1.16 mm/y mandibular growth enhancement

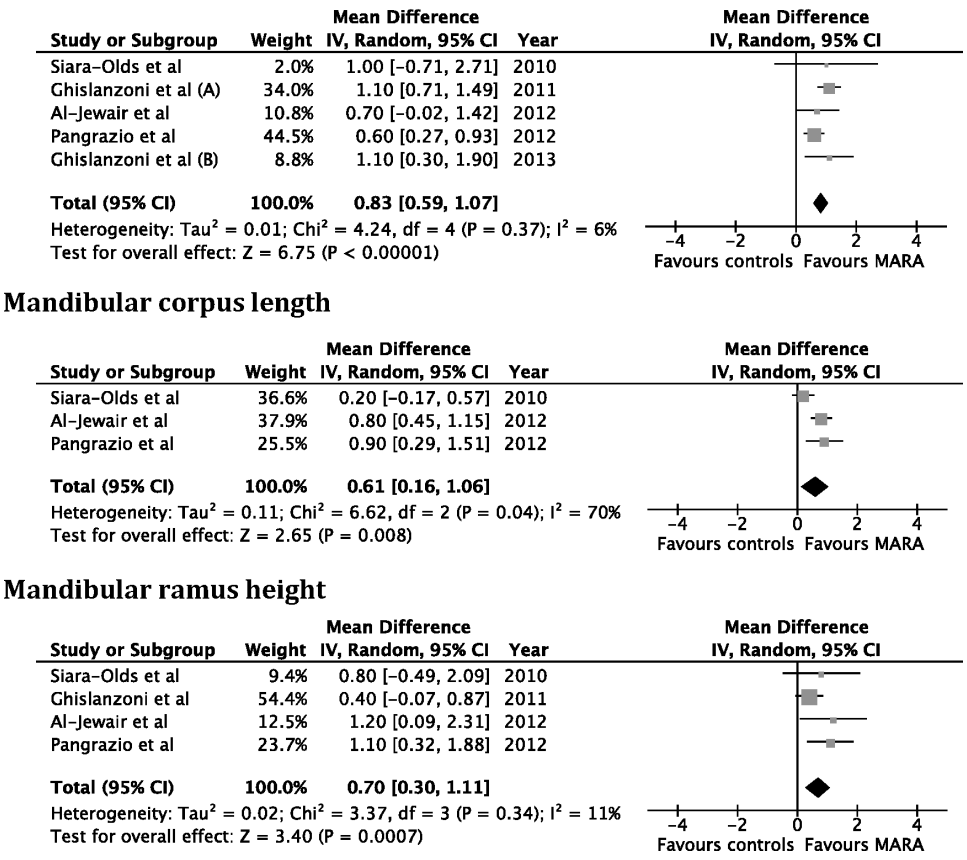


Figure 2. Forest plots of MARA vs controls for the long-term mandibular dimensions outcome.

in this review contributes only partially to the correction of the Class II malocclusion.

Statistical pooling of the MDs of the mandibular corpus length showed a nonsignificant increase with MARA and a great heterogeneity. The small number of included studies and the differences in methodologies (eg, cephalometric measurements, treatment durations, and treatment mechanics) can all explain the heterogeneity.

Ramus height increased by 1.58 mm/y in the MARA group compared with the untreated control subjects. This finding suggests that the total mandibular dimensional change was more a result of mandibular vertical development than horizontal growth. Although the MARA appliance includes stainless steel crowns that cover both the maxillary and mandibular first molars, which might restrict the natural eruption of these teeth, this did not seem to affect the skeletal elongation of the ramus.

Long-Term Effects of MARA

The increase in total mandibular unit length, corpus length, and ramus height were all statistically significantly larger in the MARA group than in the control

Table 6. Sensitivity and Subgroup Analyses for the Long-Term Mandibular Dimensions Outcome for the MARA vs Control Groups[a]

Outcome	Original Pooled Estimate (95% CI) (mm/y)	Exclusion of Low-Quality Studies (mm/y)	*P* Value for Heterogeneity	Exclusion if Sample Size per Group <20 (mm/y)	*P* Value for Heterogeneity	Exclusion Due to Different/Unclear Skeletal Baseline Features (mm/y)	*P* Value for Heterogeneity
Total mandibular unit length	0.83 (0.59, 1.07)	0.59 (0.34, 0.83)	0.77	0.63 (0.33, 0.93)	0.88	0.63 (0.33, 0.93)	0.88
Mandibular corpus length	0.61 (0.16, 1.06)	0.82 (0.52, 1.12)	0.78	0.61 (0.16, 1.06)	0.04	0.61 (0.16, 1.06)	0.04
Mandibular ramus height	0.70 (0.30, 1.11)	1.70 (0.50, 1.64)	0.89	1.07 (0.50, 1.64)	0.89	1.07 (0.50, 1.64)	0.89

[a] MARA indicates mandibular anterior repositioning appliance; CI, confidence interval.

group, but the effect sizes were small and clinically insignificant if analyzed independently of other changes. The annualized mean differences achieved in the short term diminished over time as the sample surpassed the circumpubertal growth spurt.

Clinical Significance

In summary, this meta-analysis found a statistically significant mandibular growth enhancement with MARA in both the short and long term, but the findings may not be clinically significant. In a recent study, Brignardello-Petersen et al.[24] suggested that for a result to be clinically significant, three criteria must be met: (1) the change/difference in the outcome between the groups has to be of interest to clinicians, (2) the change/difference must occur in an important outcome, (3) and the findings must be statistically significant. In this meta-analysis, the outcomes assessed are important and the changes in the mandibular growth are statistically significant. However, the pooled effect sizes are very small, when considered individually, to affect clinical decision-making.

Limitations

This meta-analysis was constrained by several limitations. The quality of the included studies was low or medium, therefore limiting the external validity of the results. Also, the varying methodologies and MARA treatment protocols may have reduced the homogeneity of the studies and weakened the pooled effect sizes. Future studies with strong designs (eg, RCTs) and rigorous methodologies (eg, similar dentoskeletal features at baseline, untreated control subjects with Class II malocclusion, and blinding of outcome assessors) are warranted. None of the studies evaluated the postretention stability effects of MARA. It is recommended that future studies evaluate all possible outcomes for changes in mandibular growth.

CONCLUSIONS

- The MARA appliance produced statistically significant mandibular dimensional changes. These findings, however, are unlikely to be of clinical significance when analyzed individually.
- Meta-analyses of the short-term effects revealed a significant increase with MARA over untreated control subjects in total mandibular unit length (1.16 mm/y), ramus height (1.58 mm/y), and a nonsignificant increase in corpus length (0.21 mm/y).
- Statistical pooling of the effects after use of fixed appliances showed a statistically significant advantage of MARA over controls in total mandibular unit length (0.83 mm/y), corpus length (0.61 mm/y), and ramus height (0.70 mm/y).

ACKNOWLEDGMENT

The author wishes to thank Dr. Carlos Flores-Mir for his comments on the manuscript.

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