

RESEARCH ARTICLE



## Effects of rapid maxillary expansion on anchorage alveolar bone meta-analysis

Ruijun Chen

Department of Orthodontic, Beijing Daxing Xingye Dental Hospital, Beijing, China

### ABSTRACT

**Purpose:** Rapid maxillary expansion (RME) is a routine method for correcting transverse maxillary deficiency. This paper investigated the effect of RME on anchorage alveolar bone and examined the differences between micro-implant-assisted RME and conventional RME.

**Methods:** Relevant articles were selected from the PubMed, EMBASE and Cochrane Central Register of Controlled Trials databases. Review Manager software (v.5.3) was used for the pooled analysis and Cochran  $Q$  and  $I^2$  statistic tests were used to assess the heterogeneity.

**Results:** Following conventional RME, the distal buccal alveolar bone thickness and the mesiobuccal alveolar thickness of the maxillary first molars were significantly reduced. Hyrax (standard mean difference [SMD]:  $-0.93$ , 95% confidence interval [CI]:  $-1.20$ – $0.66$ ) and Haas procedures (SMD:  $-0.88$ , 95% CI:  $-1.40$ – $0.36$ ) significantly reduced the buccal vertical alveolar height of the maxillary first molars. Similar results were obtained for the maxillary first premolars following RME. The thickness of the buccal alveolar bone decreased with conventional RME compared to when using the method assisted by micro-implants.

**Conclusions:** Conventional RME can reduce the thickness and vertical height of maxillary alveolar bone, and there is less loss of alveolar bone when using micro-implant-assisted RME. Further research is needed to validate the findings.

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### Introduction

Rapid maxillary expansion (RME) is a routine method used to correct transverse maxillary deficiency [1]. It enlarges the palatal suture by applying a lateral force to the tooth and the alveolar bone surrounding the tooth, increasing the width of the premolar and molar regions [2]. While RME has been recognised as a safe and reliable method for the treatment of adolescent patients [3], it causes lateral flexion of the alveolar process and buccal tilt of the affected teeth, resulting in the development of periodontal side effects, such as a loss in buccal bone thickness and marginal bone level [4–6].

The feasibility of this treatment for adult patients remains controversial due to the increased palatal midline resistance in late adolescence, and the possibility that RME may have a greater dental/periodontal impact [7,8]. Recently, micro-implant-assisted rapid palatal expansion (MARME) has been proposed for lateral skeletal correction, an approach that does not have severe periodontal side effects on the anchorage teeth and does not cause biological trauma [9,10]. When using MARME, the maxillary complex rotates and tilts less, the load is distributed directly over the palate and the pressure on the supporting tissues is lower [11].

This paper presents a systematic review of the effects of RME on the teeth and/or bones when using different methods with inconsistent results. While one previous study

concluded that the procedure has the same dental skeletal outcomes as traditional RME [12], another study suggested that bone-loaded or mixed-dental-loaded RME has the advantages of increasing the suture openings and reducing any tooth inclination [13]. There currently exists no quantitative analysis of the loss of anchorage alveolar bone following RME. The aim of this study was thus to evaluate the effect of RME on the buccal alveolar bone thickness and the vertical height of the maxillary first molars and first premolars, to provide evidence-based medical evidence for the clinical use of RME in the treatment of maxilla width deficiency, as well as for the prevention of complications and a comprehensive risk assessment. In the process, the effect of micro-implant-assisted RME is compared to that of conventional RME.

### Methods

This systematic review and meta-analysis were conducted following the Cochrane Collaboration's preferred reporting item for systematic reviews and meta-analyses (PRISMA) [14].

### Search strategy and literature screening

The PubMed, Embase and Cochrane Central Register of Controlled Trials (Central) databases were comprehensively

searched for relevant studies from database creation to publication on 22 December 2022. No language restrictions were placed on the retrieval process. We combined MeSH/Emtree terms with free words to retrieve related records, with the keywords including 'arch expansion', 'dental arch expansion', 'maxillary expansion', 'micro-implant nail', 'micro-implant', 'micro-screw', 'maxilla', 'palate', 'periodontal' and 'alveolar bone' used to identify relevant titles and summary keyword patterns. Furthermore, additional publications were manually retrieved from the reference lists of the relevant studies, reviews and meta-analyses. Based on the corresponding retrieval strategy, duplicate documents were removed from the list of documents exported from the database to Endnote X9.3.3 (Clarivate Analytics, London, UK), with the duplicate documents then removed manually. Two investigators were involved in the search of relevant records and any discrepancy were resolved by a senior investigator.

### **Inclusion and exclusion criteria**

The inclusion criteria mainly followed the PICOS principle, which includes five elements: participants, intervention, comparison, outcome and study design. The following inclusion criteria were applied: (1) the patients had insufficient maxillary width; (2) the patients were treated with conventional RME; (3) the patients with RME were treated with conventional methods; (4) the thickness or vertical height of the alveolar bone in the buccal and palatal side of the first molar or first premolar were assessed *via* computerised tomography; (5) the article presented a randomised controlled trial (RCT) or a clinical study. The exclusion criteria were as follows: (1) duplicate studies with similar data, case reports, literature reviews or abstracts; and (2) studies with incomplete or unreported outcomes.

### **Data extraction and risk of bias assessment**

Two researchers independently extracted the features and data from the retrieved studies, which mainly included the basic information of the study (author, time of publication, sample size), the basic characteristics of the patient population (age and gender), the type of appliance and the study results. The Cochrane Collaboration tool or the Newcastle-Ottawa scale (NOS) was used to assess the risk of bias in the RCTs and non-randomised studies, respectively. The Cochrane risk of bias tool is used to assess the bias pertaining to six areas: selection bias, implementation bias, measurement bias, follow-up bias, reporting bias and other bias. According to the reviewers' responses to the signalling questions, the risk of bias in each area can be classified into three levels: 'low risk of bias', 'some concerns' and 'high risk of bias'. If the bias risk of all domains is 'low risk', the overall risk of bias is 'low risk', while if some areas of the bias risk assessment results are 'there is a certain risk' and there are no 'high risk' areas, the overall risk of bias is 'there is a certain risk'; if at least one area of the bias risk assessment is 'high risk', the overall bias risk is 'high risk'. The NOS was used to

evaluate the quality of the study using a three-block, eight-item method, which included the selection of the study population, comparability, exposure evaluation or outcome evaluation, with a full score of 9 stars indicating the best quality. In the case of disagreement between the two reviewers in terms of data extraction and methodological quality assessment, this was resolved by a senior investigator.

### **Statistical analysis**

The meta-analysis was performed using Review Manager software (RevMan 5.3, Nordic Cochrane Centre, Cochrane Collaboration, Copenhagen, Denmark). In the absence of significant heterogeneity, the Mantel-Haenszel method was used for data aggregation and quantitative analysis. Cochran  $Q$  and  $I^2$  statistic tests were used to evaluate the heterogeneity. A random-effects model was used for the quantitative analysis of the data. When  $p \geq .1$  or  $I^2 \leq 50\%$ , there was no or moderate heterogeneity among the studies, while when  $p \leq .1$  or  $I^2 \geq 50\%$ , there was significant heterogeneity among the studies. Standard mean differences (SMDs) and the corresponding 95% confidence intervals (CIs) were used to analyse related outcome measures. When  $p \leq .05$ , the definition was statistically significant. In addition, subgroup analyses were conducted to assess the results of different types of studies. Publication bias regarding the primary outcome was investigated *via* visual estimation of the funnel plot.

### **Confidence in estimates**

To evaluate the confidence in estimates produced from the network meta-analysis of effectiveness outcomes, the grading of recommendations assessment, development, and evaluation (GRADE) technique was used. According to this method, the degree of confidence for direct evidence from RCTs might be reduced from high to moderate, low or very low depending on the risk of bias, indirectness, imprecision, inconsistency (or heterogeneity) and/or publication bias. Indirect estimates are evaluated starting at the lowest rating of the two pairwise estimates that operate as first-order loops, while they may be rated lower yet for imprecision or intransitivity (dissimilarity between studies in terms of clinical or methodological characteristics). The network meta-analysis estimates may be given a better ranking if the direct and indirect estimates are comparable (i.e. coherent).

## **Results**

A total of 386 electronic records were searched, including 198 in PubMed, 108 in Embase and 80 in Central. A total of 111 duplicate records were eliminated using Endnote X 9 software or manually, 241 irrelevant articles were eliminated after browsing the titles and abstracts and 22 articles with inconsistent outcome indicators or incomplete data were eliminated after reading the full text. A final total of 12 articles were included in the meta-analysis. A flow chart presenting the literature screening process is shown in [Figure 1](#).

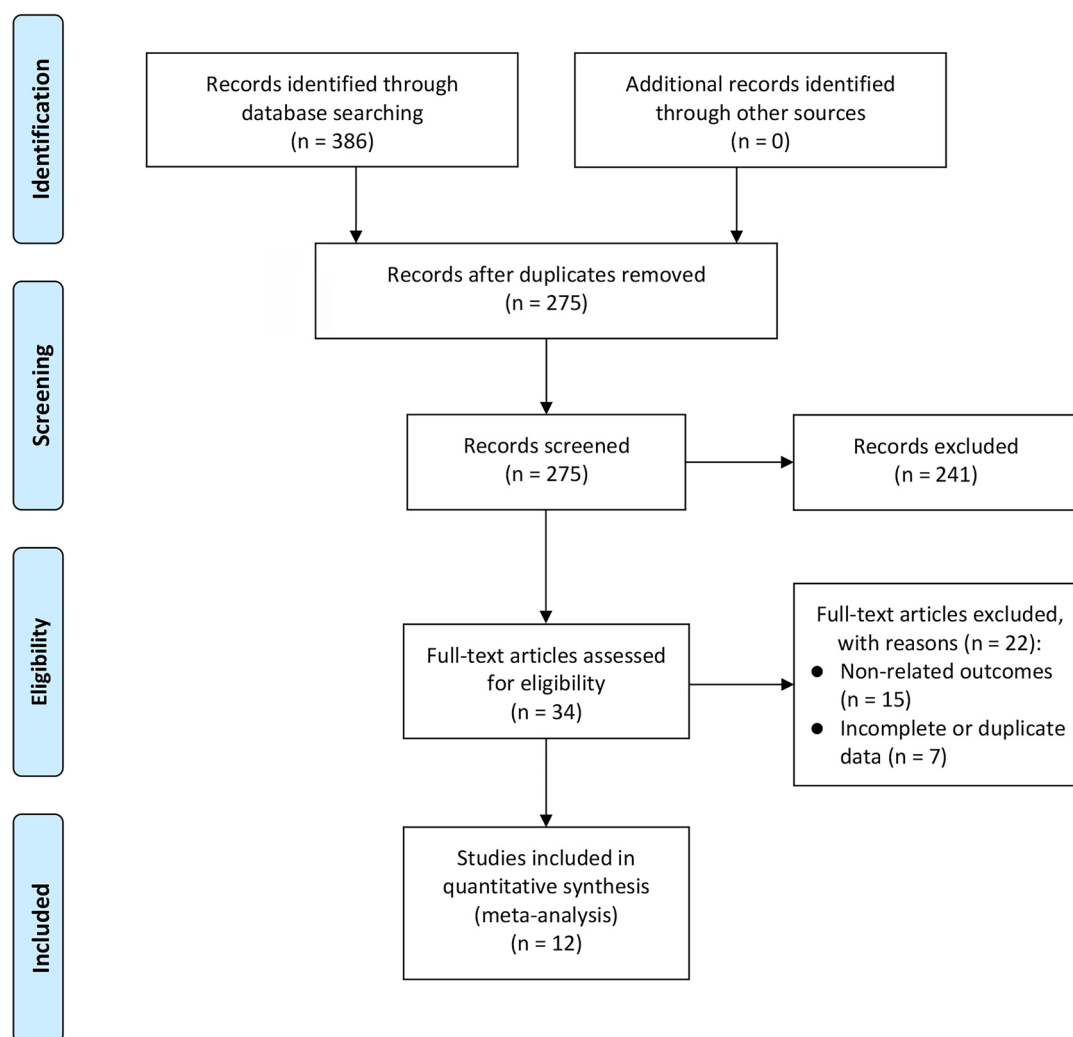


Figure 1. Flow chart of research incorporation.

### Basic characteristics of the included literature

A total of 12 articles [4,15–26] were included in this study, five of which were RCTs. The basic characteristics of the included articles are shown in Table 1. Most of the studies were carried out in the United States, Turkey and other regions, and mainly involved adolescents.

### Risk of bias assessment

The literature was assessed for quality using the Cochrane Collaboration tool or the NOS, and as shown in Table 2, two RCTs were high risk, three were unknown risk and the remaining non-RCTs were assessed in terms of quality.

### The effect of rapid maxillary expansion on the alveolar bone of the maxillary first molar

A total of five papers studied the effect of RME on the buccal alveolar bone thickness of the maxillary first molars. As shown in Figure 2, following conventional RME with four measurements, the distal-middle buccal alveolar bone

thickness (DBBT) of the maxillary first molars was significantly decreased on the left (SMD: 0.70, 95%CI: 0.40–1.00) and right (SMD: 0.78, 95%CI: 0.49–1.08) sides. Similarly, the mesiobuccal alveolar thickness (MBBT) of the maxillary first molars was also significantly reduced on the left (SMD: 0.84, 95%CI: 0.54–1.14) and right (SMD: 0.85, 95%CI: 0.55–1.16) sides. The heterogeneity within each subgroup was maintained at a low level, and there was no significant difference among the subgroups ( $I^2 = 0\%$ ). The funnel plot also revealed that the studies exhibited a symmetrical trend without significant publication bias.

A total of six articles ( $N=148$ ) studied the effect of RME on the vertical height of the buccal alveolar bone of the maxillary first molars. As shown in Figure 3, the procedures were divided into Hyrax and Haas groups depending on the type of pantograph. Five studies in the Hyrax group and three in the Haas Group were combined to reveal that following RME, the Hyrax (SMD:  $-0.93$ , 95%CI:  $-1.20$ – $0.66$ ) and Haas (SMD:  $-0.88$ , 95%CI:  $-1.40$ – $0.36$ ) procedures significantly reduced the buccal vertical alveolar height of the maxillary first molar. The heterogeneity test indicated that there was no significant heterogeneity within the subgroups ( $I^2 = 0\%$ ).

**Table 1.** Characteristics of included studies.

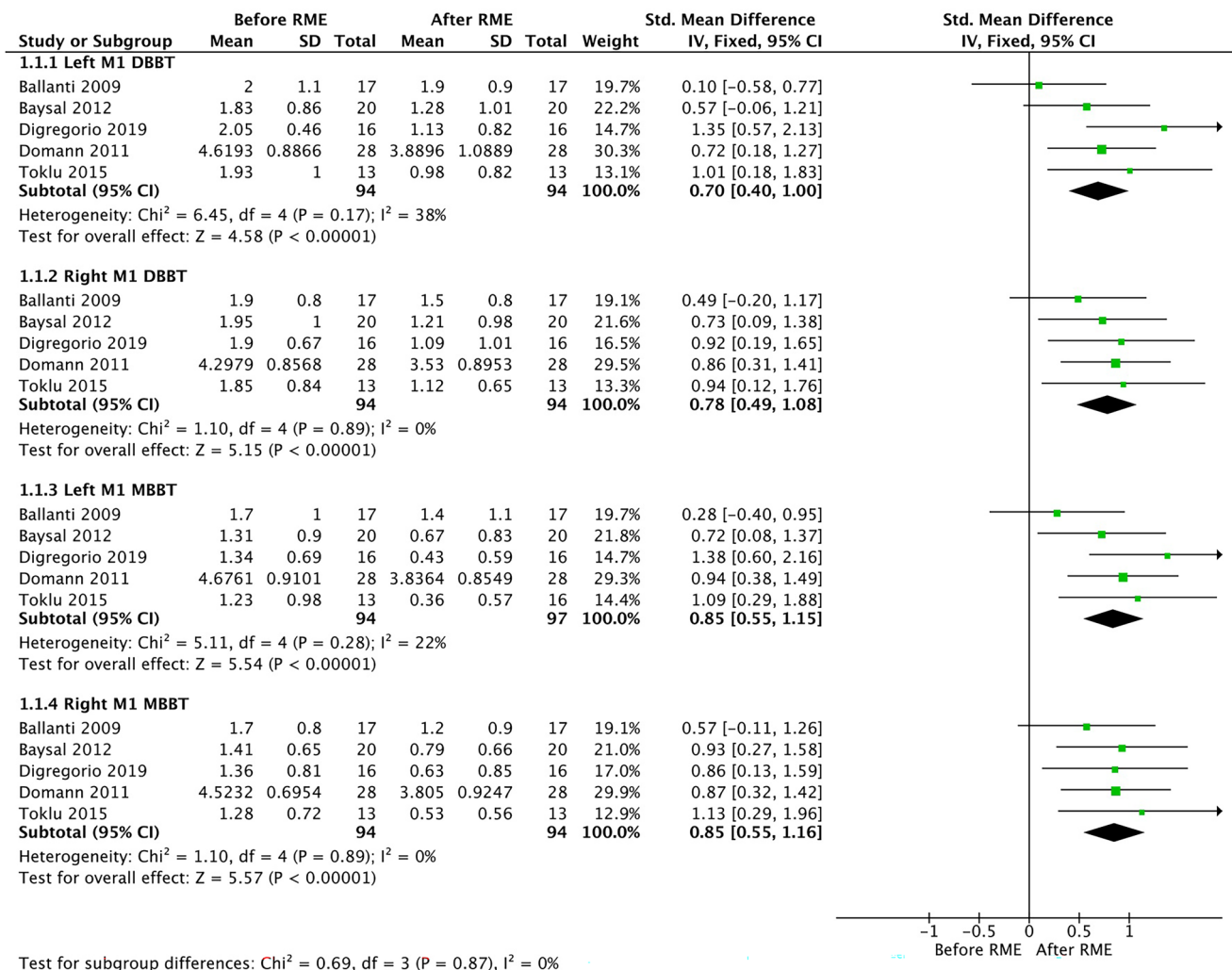
| Author (year)          | Study design  | Country       | Intervention group                                                                                                                                                                 | Control group                                                                                           | Key outcome measures                                                                                                                                                                                               |
|------------------------|---------------|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Toklu (2015)           | RCT           | Turkey        | Age 13.8±2.2 years, first molar with Hyrax dilatation screw, at left and right first premolar level, near palatal sutures, supported with 2 mini-implants (dental load dilatation) | Age 14.3±2.3 years old, Hyrax first premolars and first molars with expansion screws (dental expansion) | Buccal plate thickness: the distance from the outer edge of the buccal cortical plate to the buccal center of the first premolar root or first molar mesiobuccal root or posterior buccal root                     |
| Ballanti (2009)        | Prospective   | Italy         | –                                                                                                                                                                                  | Age 11.2(8–14) years, Haas pantograph                                                                   | The thickness of the buccal alveolar bone and the palatal alveolar bone of the first molar were measured                                                                                                           |
| Baysal (2012)          | Retrospective | Turkey        | –                                                                                                                                                                                  | Male: 13.97±1.17 years old, 13.53±2.12 years old, Hyrax arch expander                                   | The thickness and height of alveolar bone in buccal and palatal sides of maxillary first molars, the thickness and height of alveolar bone in buccal and palatal sides of left and right maxillary first premolars |
| Digregorio (2019)      | Retrospective | Italy, Canada | –                                                                                                                                                                                  | Age 13.9±1.29 years, Hyrax pantograph                                                                   | Buccal alveolar thickness of maxillary first molar                                                                                                                                                                 |
| Domann (2011)          | Prospective   | America       | –                                                                                                                                                                                  | Age 14.1 years, Hyrax archer                                                                            | Buccal alveolar bone thickness of maxillary first molar and first premolar                                                                                                                                         |
| Akyalcin (2013)        | Prospective   | America       | –                                                                                                                                                                                  | Age 13.9±2.4 years, Hyrax pantograph                                                                    | Buccal alveolar bone thickness of maxillary first molar and first premolar                                                                                                                                         |
| Garib (2006)           | RCT           | Brazil        | Age 12 years (11.4–13.6 years), Hass Bow Expander                                                                                                                                  | Age 12 years (11.5–13.9 years), Hyrax pantograph                                                        | The thickness of alveolar bone on buccal side and palatal side of maxillary first molar and the vertical height of alveolar bone                                                                                   |
| Kulbersh (2012)        | Prospective   | America       | –                                                                                                                                                                                  | Age 12.6 years old, Hyrax pantograph                                                                    | Buccal alveolar bone of maxillary first molar vertical height                                                                                                                                                      |
| Rinaldi (2018)         | RCT           | Brazil        | Age 11.6±1.5 years, Hass pantograph                                                                                                                                                | Age 11.1±1.25 years, Hyrax pantograph                                                                   | Buccal alveolar bone of maxillary first molar vertical height                                                                                                                                                      |
| Rungcharassaeng (2007) | Prospective   | America       | –                                                                                                                                                                                  | Age 13.8±1.7 years, Hyrax pantograph                                                                    | Buccal alveolar bone of maxillary first molar and first premolar vertical height                                                                                                                                   |
| Brunetto (2013)        | RCT           | Brazil        | –                                                                                                                                                                                  | Average age is 9 years old, Hass Bow Expander                                                           | Buccal alveolar bone drop vertical height                                                                                                                                                                          |
| Celenk-Koka (2018)     | RCT           | Turkey        | Age 13.81±1.23 years old, micro-implant                                                                                                                                            | The mean age was 13.84±1.36 years. The occlusal overbite of Hyrax premolar and first molar was observed | Buccal alveolar bone width: measured from the most lateral point of bone to the furcation and at the level of the third furcation of the maxillary first premolar and maxillary first molar, respectively          |

**Table 2.** Risk bias assessment.

| <i>Cochrane risk-of-bias tool</i> |                                          |                                 |                                                 |                                             |                                                 |                     |                                          |                           |             |
|-----------------------------------|------------------------------------------|---------------------------------|-------------------------------------------------|---------------------------------------------|-------------------------------------------------|---------------------|------------------------------------------|---------------------------|-------------|
| Author (year)                     | The generation of random sequences       | Allocation hiding               | Implementers and participants were double blind | Outcome Assessment Blind                    | Incomplete outcome data                         | Selective reporting | Other                                    | Total                     |             |
| Toklu (2015)                      | –                                        | –                               | –                                               | +                                           | +                                               | ?                   | +                                        | –                         |             |
| Garib (2006)                      | ?                                        | ?                               | ?                                               | ?                                           | +                                               | ?                   | +                                        | ?                         |             |
| Rinaldi (2018)                    | +                                        | ?                               | ?                                               | ?                                           | +                                               | ?                   | +                                        | ?                         |             |
| Brunetto (2013)                   | ?                                        | ?                               | ?                                               | +                                           | +                                               | ?                   | +                                        | ?                         |             |
| Celenk-Koka (2018)                | +                                        | +                               | –                                               | +                                           | +                                               | ?                   | +                                        | –                         |             |
| <i>Newcastle-Ottawa scale</i>     |                                          |                                 |                                                 |                                             |                                                 |                     |                                          |                           |             |
| Author (year)                     | Representation of the exposed population | Selection of non-exposed queues | The determination of exposure                   | The study began with no interesting results | Group comparability based on design or analysis | Outcome Assessment  | Whether the follow-up time is sufficient | Completeness of follow-up | Total score |
| Ballanti (2009)                   | *                                        | *                               | –                                               | *                                           | * <sub>1</sub> –                                | *                   | *                                        | *                         | 7           |
| Baysal (2012)                     | *                                        | *                               | –                                               | *                                           | * <sub>1</sub> –                                | *                   | –                                        | *                         | 6           |
| Digregorio (2019)                 | *                                        | *                               | –                                               | *                                           | * <sub>1</sub> –                                | *                   | *                                        | *                         | 7           |
| Domann (2011)                     | *                                        | *                               | –                                               | *                                           | * <sub>1</sub> –                                | *                   | *                                        | *                         | 7           |
| Akyalcin (2013)                   | *                                        | *                               | –                                               | *                                           | * <sub>1</sub> –                                | *                   | *                                        | *                         | 7           |
| Kulbersh (2012)                   | *                                        | *                               | –                                               | *                                           | * <sub>1</sub> –                                | *                   | *                                        | *                         | 7           |
| Rungcharassaeng (2007)            | *                                        | *                               | –                                               | *                                           | * <sub>1</sub> –                                | *                   | –                                        | *                         | 6           |

+: low risk of bias; ?: unclear risk of bias; -: high risk of bias.

\*: Newcastle-ottawa scoring award; –: the project does not score.



**Figure 2.** Effect of RME on buccal alveolar bone thickness of maxillary first molar. DBBT: distal buccal alveolar thickness; MBBT: mesiobuccal alveolar thickness.

### Effect of rapid maxillary expansion on the alveolar bone of the maxillary first premolars

A total of four articles ( $N=81$ ) studied the effect of RME on the buccal alveolar bone thickness of the maxillary first premolars. The results indicated that following RME, the buccal alveolar bone thickness of the left (SMD: 0.40, 95%CI: 0.08–0.71) and right (SMD: 0.63, 95%CI: 0.31–0.95) maxillary first premolars significantly decreased (Figure 4). The heterogeneity test revealed that  $I^2 < 50\%$  was at a lower level, while the inter-subgroup test suggested that  $I^2 = 1.9\%$ .

The effect of RME on the vertical height of the buccal alveolar bone of the maxillary first premolars was studied in three articles ( $N=78$ ). As shown in Figure 5, following RME, both the Hyrax procedure (SMD:  $-1.14$ , 95%CI:  $-1.50$ – $-0.79$ ) and the Haas procedure (SMD:  $-1.23$ , 95%CI:  $-2.85$ – $-0.40$ ) significantly reduced the buccal alveolar vertical height of the maxillary first premolars, with the difference statistically significant. There was no significant heterogeneity between the two groups ( $I^2 = 0\%$ ).

### Effects of micro-implant-assisted rapid maxillary expansion on the anchorage of the alveolar bone versus those of conventional rapid maxillary expansion

In contrast, few studies have compared micro-implant-assisted RME and conventional RME concerning anchorage of the alveolar bone, with only two articles ( $N=65$ ) identified. As shown in Figure 6, the buccal alveolar bone thickness decreased following conventional RME compared to when assisted by micro-implants, which was especially the case in the left (SMD: 1.05; 95%CI: 0.52–1.57;  $p<.001$ ) and right (SMD: 0.75; 95%CI: 0.24–1.25;  $p=0.004$ ) premolar areas, but not in the molar areas ( $p>.05$ ).

### Grading of recommendations assessment, development and evaluation assessment

Using the GRADE assessment, all outcomes regarding the buccal bone thickness and the first premolars were rated as low certainty. However, this was due to the observational design and unclear risk of bias in some of the studies. In

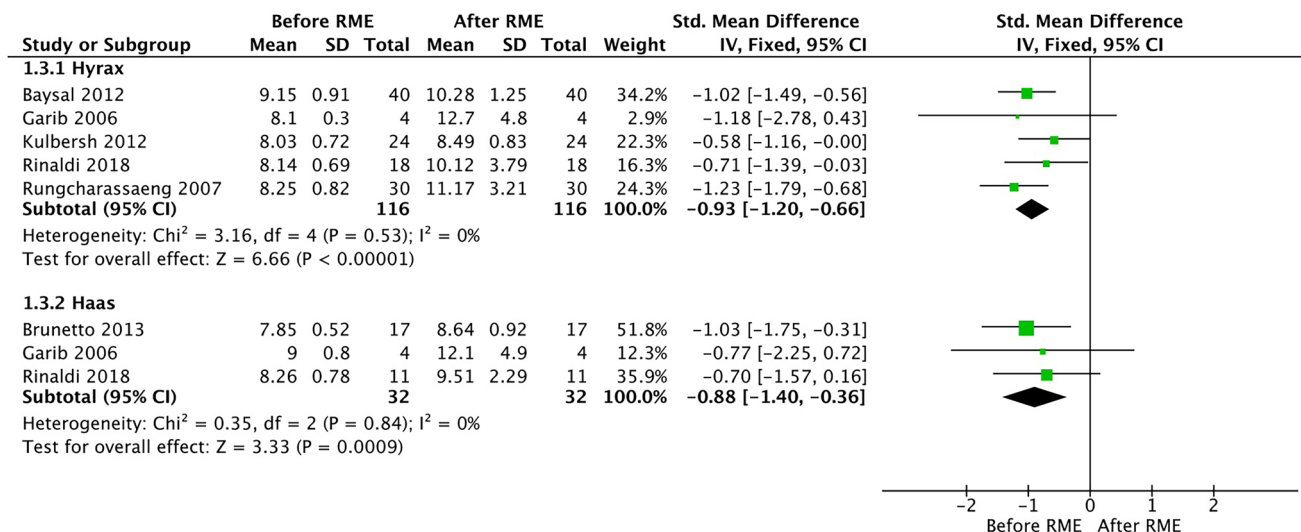


Figure 3. The buccal alveolar bone vertical height of maxillary first molar before and after RME.

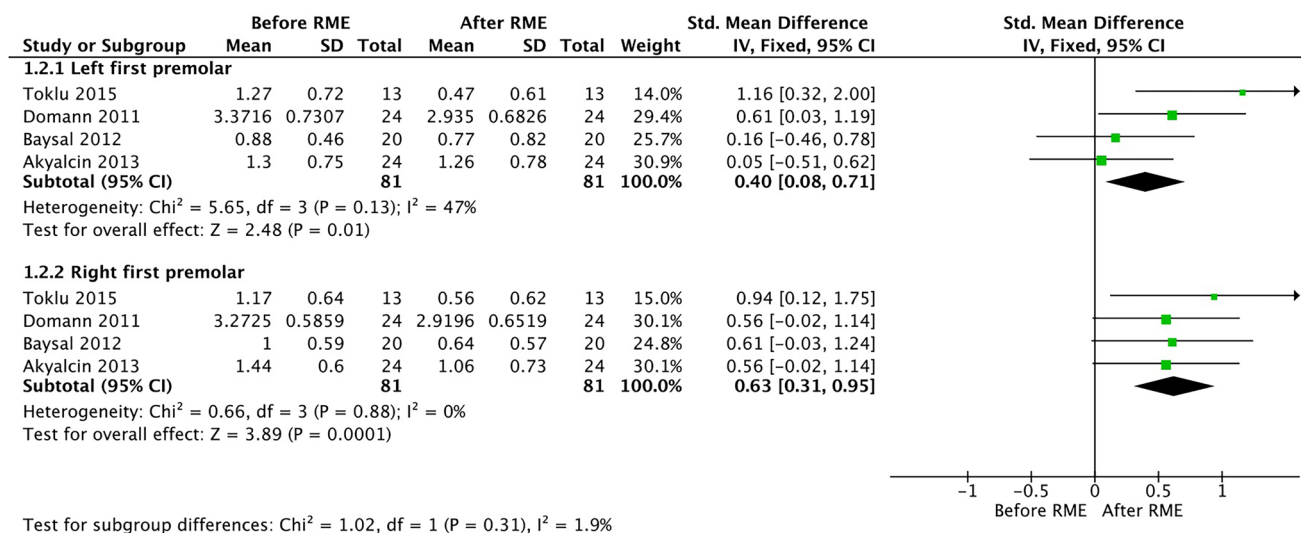


Figure 4. Effect of RME on buccal alveolar thickness of maxillary first premolar.

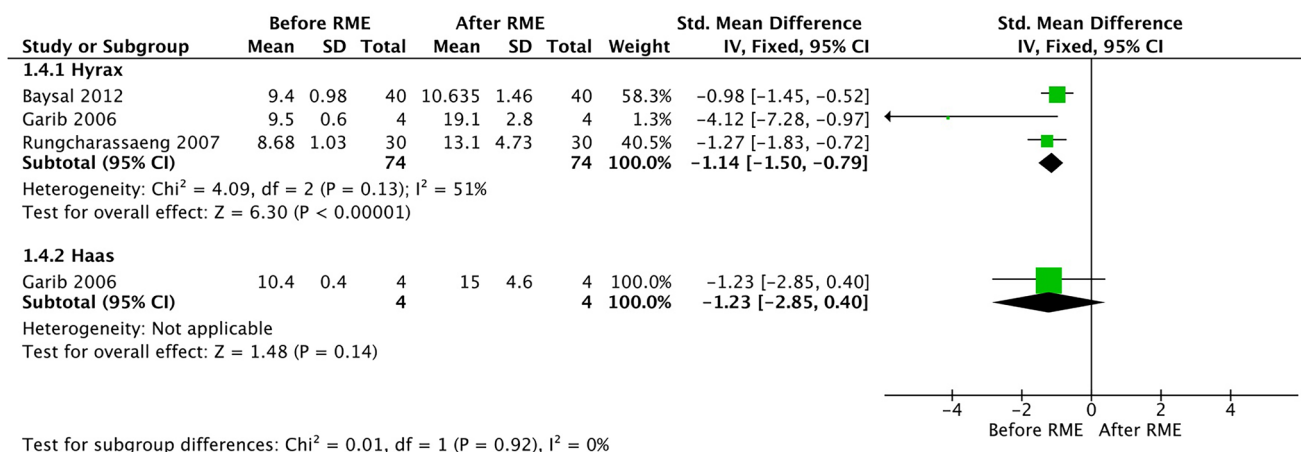
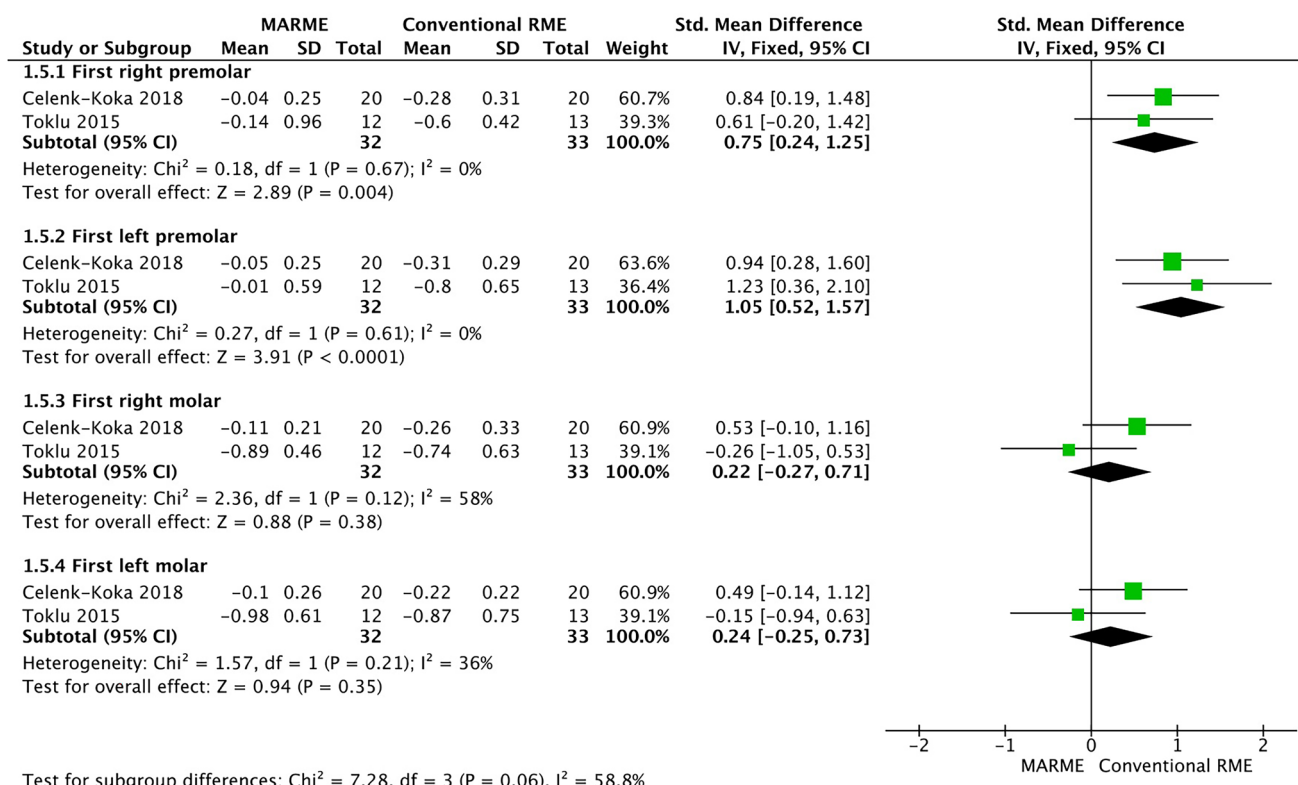


Figure 5. The vertical height of buccal alveolar bone of maxillary first premolars before and after RME.



**Figure 6.** Comparison of the effects of MARME and conventional RME on the alveolar bone of maxillary anchorage.

contrast, other outcomes were rated as moderate certainty. A complete GRADE assessment of all the outcomes is shown in [Supplementary Table S1](#).

## Discussion

The effects of RME on the buccal alveolar bone thickness and vertical height of the maxillary first molars and first premolars were evaluated systematically, and the effects of micro-implant-assisted RME on the alveolar bone were compared with those of conventional RME. The main findings of this study are as follows: (1) following conventional RME, the alveolar bone thickness of the left and right maxillary first molars significantly decreased in the distal and mesiobuccal sides, while the Hyrax and Haas procedures significantly decreased the vertical height of the buccal alveolar bone of the maxillary first molars; (2) following RME, the buccal alveolar bone thickness of the left and right maxillary first premolars significantly decreased, and the buccal alveolar bone vertical height of the maxillary first premolars significantly decreased in both the Hyrax group and the Haas group; (3) compared to the micro-implant-assisted technique, the thickness of the buccal alveolar bone decreased following conventional RME, especially in the left and right premolars. This study is expected to provide evidence-based medical evidence for the use of RME in the treatment of maxilla width deficiency, as well as for the prevention of complications and for performing a comprehensive risk assessment.

Previous systematic reviews of the effects of RME on maxillary anchorage teeth have reported mixed results [13,26]. An exploratory, systematic meta-analysis study suggested a

beneficial effect of MARME in the treatment of patients with inadequate maxillary width; however, fewer outcomes were reported for inclusion, while some of the results were based on those from one or two studies [13]. A recent meta-analysis based on observational studies found that MARME is associated with increased alveolar bone width and adverse effects on the teeth, periodontal tissue and perioral soft tissue [26]. Elsewhere, Copello et al's [27] recent meta-analysis compared the effect of MARME versus that of conventional RME on the buccal alveolar bone thickness and marginal bone level. Here, the authors found that conventional RME is associated with a greater loss in bone thickness compared to MARME.

Unlike previous reports, the current study not only provides a head-to-head comparison of the two treatment strategies but also an updated assessment of their individual effects. Building on previous studies, our systematic review clearly defined the PICOS principle and clearly described the observational indicators of interest, thus helping to reduce the heterogeneity among the studies. This was confirmed by the analysis of the intergroup results. This study's results suggest that RME significantly reduces the maxillary alveolar bone thickness and vertical height and that MARME is expected to involve fewer adverse effects. However, the number of studies that correlate MARME with RME is small, and in the future, multi-centre, high-quality randomised controlled studies will be needed to validate these findings.

A common finding following conventional RME surgery is a reduction in buccal alveolar bone thickness and the presence of bone clefts, which are mainly caused by osteoclasts that are induced to absorb bone when the teeth cross the buccal plate [4,25]. Studies have demonstrated that

periodontal changes following RME occur mainly in the anchorage teeth [4]. However, the MARME device resulted in less buccal alveolar bone loss than in the studies related to conventional RME [25,28]. In the study by Toklu et al. [15], the difference in alveolar bone loss was significant only in the premolar area since there were no anchors on these teeth. The design of the MARME device includes only anchoring the maxillary first molars, which may result in buccal displacement of these teeth and consequent bone resorption. In contrast, the first premolars are anatomically located in an upward-narrowing area, which makes this effect more pronounced. Garib et al. [4] established that in this area of the first premolars, the root is more likely to penetrate the alveolar bone when the tooth exhibits buccal movement. In addition, treatment with a mixed skeletal appliance may result in less premolar tilting compared to traditional RME [13]. All these findings could explain the superior results in this area when using MARME, i.e. its ability to cause less alveolar bone wear compared to conventional RME.

However, the number of included RCTs in this meta-analysis is small and the sample size is limited, and more high-quality RCTs are needed to further compare the effects of conventional RME and MARME on anchorage alveolar bone.

It is important to note that while the primary purpose of RME is to correct any maxillary arch discrepancies, its effects are not limited to the upper jaw and are expected to affect other adjacent structures of the face and skull. A recent study investigated the potential changes in the spheno-occipital synchondrosis and clivus following tooth-borne and bone-borne RME [29]. The three-dimensional assessment indicated that both types of RME appeared to have some effect on the adjacent structures, while the differences were non-significant. In addition, Giudice et al. [30] found that the volume of the pulp chamber of the posterior teeth was reduced more rapidly by tooth-borne RME compared to bone-borne RME. Furthermore, both types of RME could significantly increase the buccal-lingual inclination of the mandibular posterior teeth. However, no differences were found between the two groups in terms of linear or angular measurements [31].

This study involves several limitations. First, not all of the studies included in this meta-analysis were RCTs due to the limited number of studies and the definition of the observational indicators, while the retrospective studies may have led to possible selection bias. Therefore, further high-quality RCT research is needed to explore this issue. Second, the effects of anchorage on the alveolar bone are short-term, and there remains a lack of long-term follow-up results. Third, our findings cannot be extended to designs that do not use molars or premolars as the anchorage teeth due to the various designs of MARME devices. However, these two types of teeth are the focus of most studies. Finally, the quality of the literature included in this study is uneven, and most of the studies were not evaluated appropriately using blind methods, which may also pose a risk of bias in the results.

## Conclusion

To sum up, conventional RME can reduce the thickness and vertical height of maxillary alveolar bone in a short time,

and the loss of alveolar bone caused by micro-implant-assisted RME is less significant than when using conventional methods. However, more high-quality research is needed to further explore this aspect.

## Ethical approval

An ethics statement is not applicable because this study is based exclusively on published literature.

## Author contributions

Chen R conceived of the study, participated in its design and data analysis and statistics, drafted the manuscript, read and approved the final manuscript.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Data availability statement

All data generated or analysed during this study are included in this article. Further enquiries can be directed to the corresponding author.

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