European Journal of Orthodontics, 2018, 296–303
doi:10.1093/ejo/cjx057
Advance Access publication 10 August 2017

Systematic review

Alveolar bone changes after rapid maxillary expansion with tooth-born appliances: a systematic review

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Summary

Background: During rapid maxillary expansion (RME), heavy forces are transmitted to the maxilla by the anchored teeth causing buccal inclination and buccal bone loss of posterior teeth.

Objective: To systematically review the literature in order to investigate whether RME causes periodontal sequelae, assessed by cone-beam computed tomography (CBCT).

Search methods: Fifteen electronic databases and reference lists of studies were searched up to March 2017.

Selection criteria: To be included in the systematic review, articles must be human studies on growing subjects, with transversal maxillary deficiency treated with RME and with assessment of buccal bone loss by CBCT images. Only randomized and non-randomized trials were included.

Data collection and analysis: Two authors independently performed study selection, data extraction, and risk of bias assessment. Study characteristics (study design, sample size, age, sex, skeletal maturity, type of appliance, daily activation, evaluated linear measurements, observation period, CBCT settings), and study outcomes (loss of buccal bone thickness and marginal bone) were reported according to the PRISMA statement.

Results: On the basis of the applied inclusion criteria, only six articles, three randomized clinical trials and three controlled clinical trials were included. An individual analysis of the selected articles was undertaken. The risks of bias of the six trials were scored as medium to low.

Limitations: The results of the present systematic review are based on a limited number of studies and only one study included a control group.

Conclusions and implications: In all considered studies, significant loss of buccal bone thickness and marginal bone level were observed in anchored teeth, following RME. Further prospective studies correlating the radiological data of bone loss to the periodontal soft tissues reaction after RME are required. A preliminary evaluation of the patient-related risk factors for RR may be advisable when considering to administering RME.

Registration: This systematic review was registered in the National Institute of Health Research database with an appropriate protocol number (http://www.crd.york.ac.uk/PROSPERO Protocol: CRD42017062645).
Funding: The present study has not received any contributions from private or public funding agencies.

Introduction

Rapid maxillary expansion (RME) is the standard treatment for the correction of skeletal transversal maxillary deficiency (1). Tooth-borne palatal expanders, traditionally used for this purpose, are anchored to the first molars and first premolars with bands or to posterior dental unit with acrylic. During RME, heavy forces are transmitted to the maxilla by the anchored teeth and induce the hyalinization of periodontal ligament, preventing dental movement and achieving orthopaedic effect (2). However, pure skeletal opening is not attainable and unfavourable changes may occur in the anchor teeth and their supporting tissues, including vestibular dental tipping, root resorption, reduction of buccal bone thickness, and marginal bone loss (3,4). In this respect, more severe periodontal sequelae such as fenestrations, dehiscence, and/or gingival recessions represent a relevant clinical concern (5,6).

From a clinical perspective, the probing of gingival tissues and the periapical radiographic method provide direct information of patient's periodontal status. In this regard, clinical studies (7–9) reported signs of attachment loss and gingival recession after RME. However, because a quantitative assessment of bone loss is not possible from clinical observations, authors (7–9) could only speculate that RME caused buccal marginal bone loss and bone dehiscence. Moreover, conventional radiography is inadequate for periodontal diagnosis because it does not allow a precise evaluation of buccal and lingual bone thickness due to the superimposition of many structures on different planes of space (5,10).

Computed tomography (CT) or cone-beam computed tomography (CBCT) overcome the limits of conventional radiography and allow a quantitative evaluation of the buccal and lingual bone plates (4,11). Several studies evaluated the periodontal changes after maxillary expansion by using CT or CBCT, however conflicting results have been reported in relation to changes of buccal bone thickness (4,5,12,13).

The aim of the present systematic review was to evaluate, with an evidence-based approach, the periodontal effects of RME on posterior permanent teeth. We limited our search strategy to studies performed by CBCT because it provides 3-D images of dental structures without projection errors and with less artifacts compared to conventional CT (14). Moreover, only prospective clinical studies were included. In fact, according to the GRADE Working Group, only systematic review including well-designed prospective trials can reach the highest level of evidence.

Materials and Method

The present systematic review is consistent with the guidelines of the *Cochrane Handbook for Systematic Reviews of Interventions* (version 5.1.0) and is reported according to the PRISMA statement (15,16).

Two authors (ALG and RL) independently carried out the selection of the studies, data collection, and the assessment of risk of bias. Any disagreement was resolved by discussion with a third author (EB). This study was registered in the National Institute of Health Research database with an appropriate protocol number (http://www.crd.york.ac.uk/PROSPERO Protocol: CRD42017062645).

Search method

Searches were conducted on several electronic databases to find out articles concerning the effects of non-surgical skeletal maxillary expansion on buccal alveolar bone, published up to March 2017. Specific electronic databases were also searched for conference abstracts, dissertations, conference proceedings, and unpublished literature (grey literature). The strategy search was adjusted for each database and is reported in Supplementary Table 1. The reference lists of the articles eligible for inclusion were also manually reviewed. No restriction was applied to language, publication year, or status. Finally, authors were contacted to obtain specific data or info not provided in their article.

Selection of studies

According to the population, intervention, comparison, outcome, study design (PICOS) format, the following inclusion criteria were selected to assess the eligibility of the studies: related human clinical studies; studies conducted on growing patients with maxillary transverse deficiency (Population); non-surgical RME therapy (Intervention); control group represented by pre-treatment measurements of buccal bone thickness and marginal bone height of posterior permanent teeth (Comparison), assessed by CBCT; post-treatment measurements of buccal bone thickness and marginal bone height of the same teeth (Outcomes measured); randomized or non-randomized clinical trials (Study design). Duplicate reports were excluded and articles reporting interim outcomes or updates were considered only once. Randomized clinical trials and prospective controlled clinical trials including patients who had the following characteristics were excluded: previous orthodontic treatment, periodontal diseases, endodontic treatment of posterior teeth, tooth agenesis or with anomalies in form, shape, or structured and congenital syndromes.

The authors screened all titles and abstracts retrieved from the databases and reviewed the full texts of the potentially relevant studies. The reference lists of the studies were also screened to retrieve additional eligible articles. The level of agreement between the two reviewers was assessed by the Cohen's kappa statistics.

Data collection

Data extraction form was developed to collect the characteristics (study design, sample size, age, sex, skeletal maturity, type of appliance, daily activation, evaluated linear measurements, observation period, CBCT settings) and the outcomes of the included studies. The Cohen's kappa statistics was performed to assess the agreement between the two authors. To evaluate buccal bone thickness, the following linear parameters were registered: (1) on coronal scan, the measurements of linear distance between the root surface and the outer profile of buccal bone surface taken over the cement–enamel junction and (2) on the axial scan, the measurements of linear distance between the external border of the buccal cortical plate and the centre of buccal radicular aspect of the evaluated teeth.

To evaluate buccal bone height (marginal level), the measurements of the distance between the buccal cusp tip and the most occlusal point of the alveolar crest were registered.

Assessment of risk of bias

Risk of bias assessment was performed using the Downs and Black scale (17) as suggested by the *Cochrane Handbook for Systematic Reviews of Interventions* (15,16). The instrument consisted of 27 questions evaluating: (1) reporting [10 questions], (2) external validity [3 questions], (3) internal validity, bias [7 questions], (4) internal validity, confounding, selection bias [6 questions], and (5) power [1 questions]. According to this scale, answers were scored from 0 to 1 point, except for one item in the reporting domain (question n.5), which was scored from 0 to 2 points. In the original method of the Downs and Black scale, the last question is scored from 0 to 5 points; we simplified the assessment of the last question scoring this answers 0 or 5 points, giving 5 points in case of the existence of a preliminary power analysis calculation. Consequently, the total maximum score a prospective controlled clinical trial was able to receive was 32 points, with a higher score indicating higher methodological quality. The level of agreement between the two review authors was assessed with the Cohen's kappa statistic.

Data analysis

Meta-analysis of the extracted data would have been considered only if the methodology was consistent among the included studies and if they reported equivalent linear measurements of buccal bone thickness and marginal bone level. The level of agreement between the two investigators was assessed with the Cohen's kappa statistics.

Results

Selection of studies

Overall, 2511 articles were initially identified and 1726 remained after duplicates' removal; a total of 1712 articles were excluded after the reading of titles and abstracts and the full texts of the remained 14 articles were retrieved. After reading the full texts of those studies, six articles (12,18–22) were considered eligible for the final inclusion in the present systematic review. Figure 1 shows the flow diagram for the selection of studies, and the excluded articles alongside with the reasons for their exclusions are shown in Supplementary Table 2. The agreement between the reviewers was highly reliable, with a kappa value of 0.987.

Study characteristics

The characteristics of the six studies included in this systematic review are summarized in Table 1. Three studies were designed as

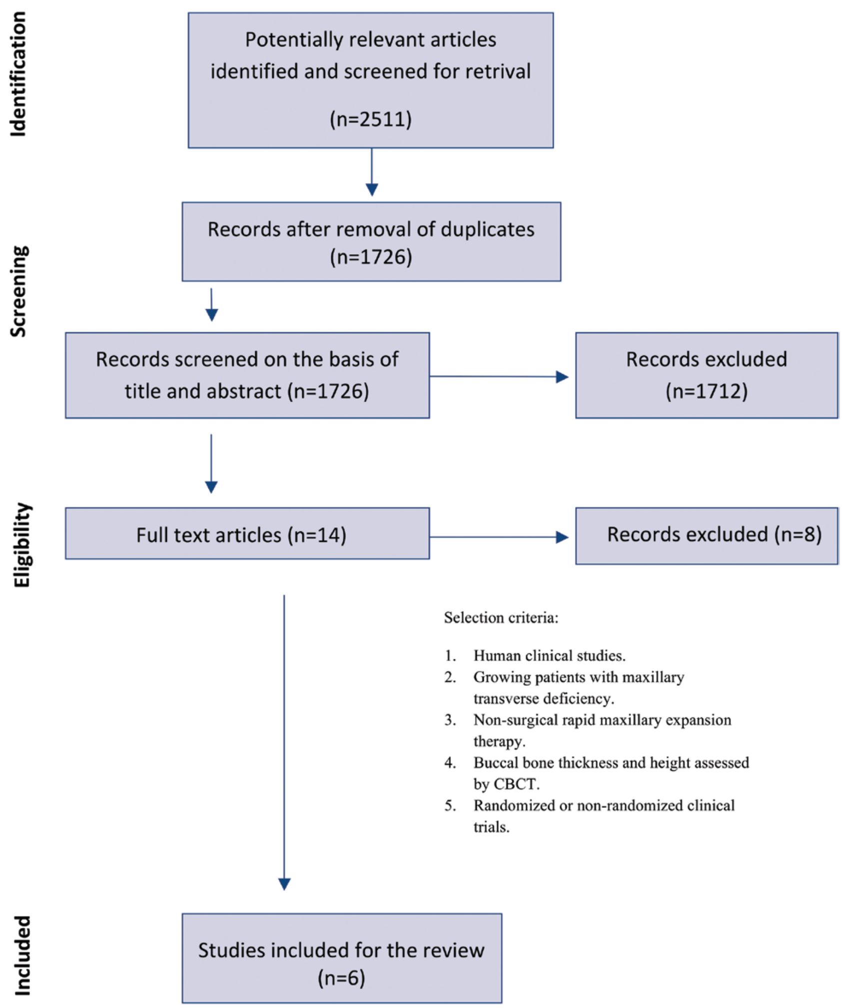

Figure 1. Flow chart of study selection performed according to the PRISMA guidelines.

Table 1. Characteristics of the studies considered for the final analysis. C BBT, canine buccal bone thickness; C PBT, canine palatal bone thickness; CEJ 3, distance between the outer surface of the buccal alveolar plate and the outer wall of the buccal root of first molars, 3 mm above the cementoenamel junction; CEJ 5, distance between the outer surface of the buccal alveolar plate and the outer wall of the buccal root of first molars, 5 mm above the cementoenamel junction; E.T., exposition time; kV, kilovolt; M1 BBT, first molar buccal bone thickness; M1 BMBL, first molar buccal marginal bone level; M1 DB C-BM, first molar distobuccal cusp to marginal bone; M1 DBBT, first molar distobuccal bone thickness; M1 DP C-BM, first molar distopalate cusp to marginal bone; M1 MB C-BM, first molar mesiobuccal cusp to marginal bone; M1 MBBT, first molar mesiobuccal bone thickness; M1 MP C-BM, first molar mesiopalate cusp to marginal bone; M1 PBT, first molar palatal bone thickness; mA, milliamper; NOV, distance between the buccal CEJ of first molars and the most occlusal point of the buccal alveolar crest; P1 B C-BM, first premolar buccal cusp to marginal bone; P1 BBT, first premolar buccal bone thickness; P1 BMBL, first premolar buccal marginal bone level; P1 PBT, first premolar palatal bone thickness; P1 P C-BM, first premolar palatal cusp to marginal bone; P2 B C-BM, second premolar buccal cusp to marginal bone; P2 BBT, second premolar buccal bone thickness; P2 BMBL, second premolar buccal marginal bone level; P2 P C-BM, second premolar palatal cusp to marginal bone; P2 PBT, second premolar palatal bone thickness; PM1, first permanent molars; PP1, first permanent premolars; V.S., voxel size.

Studies	Study design	Type of appliance	Sample size	Mean age (years)	Sex	Skeletal maturity	Teeth	Daily activation	CBCT settings	Observation period	Results linear measurements of bone thickness and alveolar bone height T2–T1 (mm)
Brunetto *et al.* (18)	Randomized trial	Haas expander	33 subjects	9	18 girls 15 boys	—	PM1 DM1	0.4 mm	20 mA; 120 kV E.T.: 14.7 s V.S.: 0.25 mm	T1: before treatment T2: between 1 and 7 days after stabilization of the screw	CEJ 3: −0.88 CEJ 5: −0.60 NOV: −0.75
Gunyuz Toklu *et al.* (20)	Randomized trial	Hyrax expander	25 subjects	14.3 ± 2.3	14 girls 11 boys	—	PM1 PP1	0.5 mm	3.8 mA; 120 kV E.T.: 40 s V.S.: 0.2 mm	T1: before treatment T2: at the end of 3 months of retention	Right/left M1 MBBT: −0.74 ± 0.63/−0.87 ± 0.75 M1 DBBT: −0.73 ± 0.74/−0.95 ± 0.71 M1 PBT: 1.72 ± 0.73/1.75 ± 0.64 P2 BBT: 0.11 ± 0.41/−0.34 ± 0.55 P2 PBT: 0.93 ± 0.99/0.21 ± 0.75 P1 BBT: −0.60 ± 0.42/−0.80 ± 0.65 P1 PBT: 1.01 ± 1.10/1.53 ± 0.82 C BBT: −0.0013 ± 0.20/0.12 ± 0.53 C PBT: −0.06 ± 0.71/0.16 ± 0.62
Dogra *et al.* (19)	Prospective study	Bonded Hyrax expander	10 subjects	From 12 to 15 years	4 girls 6 boys	Skeletal age between 12 and 16 years	Posterior (not specified)	0.4 mm	5 mA; 120 kV E.T.: 20 s V.S.: 0.25 mm	T1: before treatment T2: immediately after expansion (average expansion time 4–6 weeks)	Right/left M1 BBT:−0.81/−0.32 M1 PBT: 0.67/0.76 P2 BBT: −0.80/0.71 P2 PBT: 0.83/0.92 P1 BBT: −0.37/−0.48 P1 PBT: 0.27/0.64

Table 1. *Continued*

Studies	Study design	Type of appliance	Sample size	Mean age (years)	Sex	Skeletal maturity	Teeth	Daily activation	CBCT settings	Observation period	Results linear measurements of bone thickness and alveolar bone height T2–T1 (mm)
Pangrazio-Kulbersh *et al.* (21)	Prospective study	Hyrax expander Bonded Hyrax expander	22 subjects 10 (bonded) 12 (banded)	13.5 ± 2.1 (bonded) 12.5 ± 1.6 (banded)	11 girls 11 boys	Cervical vertebra maturation was stage 3	PM1	0.25 mm	18,54 mA; 120 kV E.T.: 8.9 s. V.S.: 0.3 mm.	T1: before treatment T2: 6 months after last activation, coincided with appliance removal	Right/left Banded group M1 BBT: −0.50/−0.53 P1 BBT: −0.73/−0.46 M1 BMBL: 0.63/0.30 P1 BMBL: 0.16/0.37 Bonded group M1 BBT: −0.55/−0.36 P1 BBT: −0.49/−0.55 M1 BMBL: 0.20/−0.66 P1 BMBL: −0.67/−0.44
Pham *et al.* (22)	Randomized trial	Hyrax expander	62 subjects 20 (tooth-anchored group) 21 (control group)	—	—	—	PM1 PP1	0.5 mm	6.19 mA; 110 kV V.S.: 0.25 mm.	T1: before treatment T2: at removal of the appliance, 6 months after insertion	Right/left M1 MB C-BM: −0.70/−0.55 M1 DB C-BM: −0.99/−0.23 M1 MP C-BM: −0.39/0.41 M1 DP C-BM: −0.59/0.11 P2 B C-BM: −0.33/−0.50 P2 P C-BM: −0.40/−0.05 P1 B C-BM: −0.55/−0.62 P1 P C-BM: −0.22/−0.19
Rungcharassaeng *et al.* (12)	Prospective study	Hyrax expander	30 subjects	13.8 ± 1.7	13 girls 17 boys	—	PM1 PP1	0.83 mm per week	—	T1: before treatment T2: within 3 months after the end of activation	Right/left M1 BBT: −1.27 ± 0.62/−1.21 ± 0.49 P1 BBT: −1.06 ± 0.58/−1.23 ± 0.71 P2 BBT: −0.82 ± 0.56/−0.86 ± 0.58 M1 BMBL: −3.27 ± 3.34/−2.56 ± 2.87 P1 BMBL: −4.10 ± 4.46/−4.75 ± 4.83 P2 BMBL: −1.31 ± 2.21/−1.44 ± 2.10

randomized clinical trials (18,20,22) and three studies were designed as controlled clinical trials (12,19,21). All the selected articles investigated the buccal alveolar bone changes of posterior teeth after RME by CBCT. All studies took place in a university setting and included both male and female participants. The mean age of the patients was similar in three studies: 14.3 years (20), 13.5 years (21), and 13.8 (12). One study reported a mean age of 8.9 years (18), one study reported only the range of age which was from 12 to 15 years (19), and one study did not reported info about patients' age (22). The untreated control group was reported only in one investigation (22). The following types of maxillary expander were used: Hyrax expander with bands on the first premolars and first molars (12,20,22), Hyrax expander with extended arms to the second and first premolars (12,21), Haas expander with bands on the first premolars and first molars (18) and bonded Hyrax expander (19,21). The protocol of expansion ranged from 0.25 mm to 0.50 mm of daily activation (12,18–22). One study (21) reported data of skeletal maturity that were based on cervical maturation system (23). The timing of radiological assessment was different among the three studies: immediately after the active treatment phase (18,19), within 3 months of appliance retention (12) and after 3 months (20) and 6 months (21,22) of appliance retention. According to the methodologies used, all the included studies assessed buccal alveolar bone thickness while four studies assessed the marginal bone level (12,18,21,22). Three studies (19,20,22) also reported data of palatal bone thickness. No studies performed periodontal prophylaxis either before or after RME protocol. Heterogeneity was found for the methodology applied and the linear measurements of alveolar bone thickness: three studies measured alveolar bone thickness from coronal scan (12,18,21) while two studies performed measurements of bone thickness on the axial scan (19,20). All CBCT images were at high resolution with different exposure parameters and with a reported voxel size ranging from 0.20 mm to 0.30 mm. The agreement between reviewers was highly reliable with a kappa value of 0.96.

Assessment of risk of bias

The risks of bias of the 6 trials were scored as medium (18,20,21) to low (12,19,22) quality, with an average score of 17 of 32 in accordance with to the Downs and Black scale (17) (Table 2). The agreement between reviewers was highly reliable with a kappa value of 0.934.

Data analysis

A meta-analysis was not feasible due to the heterogeneity in study designs and the scarce number of studies included with comparable linear measurements. Consequently, the risk of bias across the studies could not be performed and a descriptive analysis of the reported results was conducted.

Discussion

To the best of our knowledge, this is the first systematic review investigating the existing literature in order to evaluate the periodontal sequelae occurring after RME, as assessed *in vivo* by CBCT. We performed a wide and accurate bibliographic search and we found only six articles eligible for inclusion. A meta-analysis was not possible because of the differences in the study design and the scarce number of studies with comparable linear measurements. Hence, we reported a descriptive analysis of the obtained results.

According to the findings of this systematic review, RME causes reduction of both alveolar buccal bone thickness and marginal bone level of anchored teeth. Table 1 shows the mean differences of alveolar buccal bone thickness and marginal bone level found in the included studies between pre- and post-expansion phases. All measurements of buccal bone thickness were located near the occlusal edge of the alveolar bone crest; as a consequence, they could be directly influenced by changes in the marginal bone level. The thinning of alveolar buccal bone at level of first molars and first premolars was on average less than 1 mm in all included studies except for Rungcharassaeng (12) which found respectively 1.27 (right)/1.21 (left) mm (data based on measurements taken at level of the mesiobuccal root of first molar) and 1.06 (right)/1.23 (left). Concerning the reduction of marginal bone level, even in this case the values reported were less than 1 mm in all included studies, except for Rungcharassaeng (12) which found 3.27 (right)/2.56 (left) mm for the first molars and 4.10 (right)/4.75 (left) mm for first premolars. A possible explanation for such differences is that Rungcharassaeng reported an activation rate compatible with slow maxillary expansion (0.83 mm per week); in this respect, literature suggests that this expansion protocol causes more severe loss of buccal bone than RME (18,24).

In the palatal portion of the tooth, an increment of bone thickness of first molars and premolars was observed after RME in the only two studies assessing this parameter (Table 1). This trend can be attributed to the buccal movement of the posterior teeth, which increases the distance between the palatal cortical plate and the root surfaces (4,25).

Rungcharassaeng (12) and Dogra (19) reported also reduction of buccal bone thickness and marginal bone level of 2nd premolars (12,19). However, in these studies (12,19), 2nd premolars were subjected to buccal displacement because they were involved respectively in the wire-supported anchorage system and in the acrylic plate connected to the framework's appliance. On the contrary, when the palatal expander was not anchored to the 2nd premolars no significant buccal or palatal bone changes were recorded, as shown by other two included studies (20,22). This is in agreement with previous retrospective findings (4,25).

Most of the data available from the present systematic review are limited to short-term and medium-term assessment of periodontal

Table 2. Risk of bias evaluation of selected studies.

Studies	Reporting 0–11	External validity 0–3	Bias 0–7	Confounding 0–6	Power 0–5	Overall 0–32
Brunetto *et al.* (18)	8 out of 11	1 out of 3	5 out of 7	2 out of 6	5 out of 5	21 out of 32
Toklu *et al.* (20)	8 out of 11	1 out of 3	5 out of 7	4 out of 6	5 out of 5	23 out of 32
Dogra *et al.* (19)	6 out of 11	1 out of 3	4 out of 7	1 out of 6	0 out of 5	12 out of 32
Pangrazio-Kulbersh *et al.* (21)	8 out of 11	1 out of 3	5 out of 7	0 out of 6	5 out of 5	19 out of 32
Pham *et al.* (22)	6 out of 11	1 out of 3	5 out of 7	3 out of 6	0 out of 5	15 out of 32
Rungcharassaeng *et al.* (12)	8 out of 11	1 out of 3	5 out of 7	2 out of 6	0 out of 5	16 out of 32

sequelae of RME. In fact, two studies (18,19) have taken CBCT records immediately after the activation phase, while in four studies patients underwent CBCT examinations after the retention period, which ranges from 3 to 6 months.

However, it would be relevant to investigate the periodontal status in the long-term. Nguyen (26) and Alkyalcin (13) investigated retrospectively the long-term periodontal effects of RME by CBCT records obtained after the completion of orthodontic treatment. The authors found a substantial recovery of buccal bone width due to the uprighting of the molar and premolar roots induced by the fixed orthodontic appliance. Also, Greenbaum (9) observed good periodontal conditions 3 years after fixed appliance removal in a sample of subjects that underwent RME, compared to the untreated group. In the light of these findings, prospective long-term CBCT studies are required to quantitatively assess buccal bone recovery after RME.

Despite the present systematic review confirm that RME causes buccal bone loss of anchored teeth (less than 1 mm, in most of the included studies), the clinical relevance of these findings is still questionable. In fact, data of buccal bone loss must be interpreted considering the clinical periodontal condition, i.e. how periodontal soft tissues react to the application of expansive forces. In this respect, the included studies were limited to the radiological assessment of bone loss and did not perform a comparative clinical assessment of periodontal status before and after RME. Literature suggests that gingival recession should not be expected immediately after RME because migration of junctional epithelium and loss of connective attachment do not follow the apical displacement of the buccal alveolar crest, especially in the absence of inflammation (4, 27,28). Even a long connective attachment does not affect the soft tissue periodontum of supporting teeth (4). In the long-term, however, if tissue thin out after lateral expansion, gingival recession may occur due to (1) lower resistance to mechanical irritation (tooth brushing), (2) thin keratinized mucosa, which may cause recession rather than pocketing, (3) reduced bone thickness or bone dehiscence, (4) buccally displaced teeth. Thus, a preliminary evaluation of these factors is advisable when correction of maxillary transversal deficiency is required (29,30).

CBCT imaging has many advantages over conventional radiography and CT in the evaluation of dentofacial structures (31). Measurements of buccal bone thickness and height performed on CBCT images showed excellent accuracy and reliability, as compared to direct measurements on cadavers (32). However, it should be considered that such accuracy can be affected by the spatial resolution which is, in turn, influenced by voxel size, field of view (FOV), quality of images, and metal artifacts (33,34). According to Wood (34), voxel size smaller than 0.3 mm would adequately reduce the influence of partial volume effect when measurements of buccal bone thickness are required. In the present review, all included studies reported values of voxel size below 0.3 mm except for the study of Pangrazio *et al.* (21) which used a voxel size 0.3 mm; however, the multifactorial nature of spatial resolution and the fact that most of the studies included did not reported the FOV used, make any attempt to compare data useless. Moreover, in the studies of Brunetto (18) and Rungcharassaeng (12), CBCT examinations were acquired at T2 with the palatal expander in place, this could have generated artifacts in the area of measurements due to the presence of metal bands. As consequence, we can hypothesize that the difference of bone thickness between T1 and T2 found in these three studies could be partially attributed to methodological bias.

The results of the present systematic review are based on a limited number of studies. We employed bias assessment tool and we scored the risk of bias as medium to low. Also, only one study included a control group. The observation of untreated patients would be important to differentiate natural skeletal growth from changes derived from treatment. Thus, the results of this systematic review should be considered with caution. Further prospective 3D studies, with adequate control groups and long-term CBCT examinations are required in order to quantitatively assess the periodontal status of posterior teeth after RME therapy. However, this is hardly possible due to the recommendations of the British Orthodontic Society and the American Association of Orthodontists concerning the use of CBCT and the risks related to ionizing radiation exposure for each patient (35–37).

Clinical implications

The clinical implications of loss of buccal bone thickness and height after RME remain unclear, especially in the long-term. Clinicians might be blinded to the periodontal side effects induced by RME because soft tissue might hide severe sequelae of underlying periodontal structures, such as fenestration or dehiscence (31). Thus, we suggest clinicians: (1) to perform a preliminary evaluation of gingival biotype (38), (2) in mixed dentition, to use primary first molars as anchored teeth if they are steady, (3) to avoid RME in youngster insofar higher forces are applied to the dentition due to the difficulty in opening the mid-palatal suture (39). In this last case, clinicians may refer to surgically assisted expansion procedures or orthognathic surgery for the treatment of transversal maxillary deficiency. When posterior teeth are at higher risk of periodontal damage and the amount of maxillary transversal deficiency does not justify such invasive surgical procedures, a bone–born palatal could represent a valid alternative (40).

Supplementary material

Supplementary data are available at *European Journal of Orthodontics* online.

Conflict of Interest

None to declare.

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