Review Article

Bone-Borne Maxillary Expansion and Traditional Rapid Maxillary Expansion: A Systematic Review and Meta-Analysis

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Abstract

Introduction: The aim of this study was to perform a systematic review and meta-analysis to compare the effect of bone-borne expansion (BBE) and tooth-borne expansion (TBE) in patients with maxillary constriction. **Methods:** Electronic databases, including MEDLINE, EMBASE, and Cochrane Central Register of Controlled Trials, were searched up to February 2019. Eligible clinical trials and cohort studies that studied the effects of bone-borne and tooth-borne expansion appliances on patients with constricted maxilla were selected. The study selection, data extraction, and risk of bias assessment were independently performed by two authors. Then, the random-effects meta-analysis and post-hoc heterogeneity tests were performed. **Results**: In the end, four studies were included in the present meta-analysis (i.e., a randomized clinical trial, two prospective controlled clinical trials, and a cohort study) that collected data from 117 patients. The mean differences between TBE and BBE were 0.38 mm and -0.28 mm for premolar and molar apices, 0.67 mm and 1.18 mm for premolar and molar crowns, 0.19 mm and 0.17 mm for alveolar bone in premolar and molar areas, and -0.61 mm and 0.02 mm for nasal and maxillary bones, respectively. Moreover, the differences between TBE and BBE for dental angulation were 3.84◦ and 1.52◦ for left and right molars, as well as 4.85◦ and 3.46◦ for left and right premolars, respectively. **Conclusion:** The BBE appliances do not have any advantages over tooth-borne devices with regard to the amount of skeletal or dental expansion; however, it seems to produce less tipping in posterior teeth.

Keywords: Palatal Expansion Technique; Orthodontic Appliances; Fixed; Orthodontic Anchorage Procedures

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Introduction

Transverse maxillary deficiency is one of the common orthodontic problems that is usually accompanied by posterior cross-bite and dental crowding (1, 2). To eliminate posterior cross-bite and increase arch perimeter maxillary expansion should be considered (3). Various methods have been used for resolving this problem in adolescents. The most common method was performed by a hyrax (i.e., hygienic rapid palatal expander appliance) (Tooth-anchored) (4, 5). However, with this tooth-anchored device, the resulted expansion is both dental and skeletal. Other disadvantages include the risk of root resorption, gingival recession, and fenestrations (6, 7, 8).

An alternative method is bone-borne appliances. These appliances are anchored from the palatal surfaces of maxilla with Temporary Anchorage Devices (TADs). It has been claimed that these appliances caused less buccal tipping and more skeletal effects (9-13) however, there are other studies that claimed there is no difference between bone-borne and tooth-borne appliances (14-17). The aim of this study was to perform a systematic review and meta-analysis to compare the effects of bone-borne expansion (BBE) and tooth-borne expansion (TBE).

Methods and Materials

We conduct this systematic review and meta-analysis in line with the guidelines of the Cochrane Handbook for Systematic Reviews of Interventions (version 5.1.0) and PRISMA statement. Studies about different appliances for the treatment of posterior cross-bite were searched through different electronic databases, such as MEDLINE, EMBASE, and Cochrane Central Register of Controlled Trials. An electronic search for IADR conference proceedings was also conducted. The time frame for studies was from the beginning to February 2019. The search strategy was adjusted for different databases (Table II). A hand search was also performed on eligible article reference lists for related articles. Any non-English articles were translated, and their data were extracted. Any data not mentioned in the article was obtained from the authors or the article was excluded from the review.

Selection of studies

The relevant clinical trials and cohort studies were selected with the following PICO format:

related human clinical trials and cohort studies, studies on patients with maxillary constriction (i.e., population), orthodontic treatment conducted with BBE appliance (i.e., intervention), orthodontic treatment conducted with a TBE appliance (i.e., comparison), results analyzed using cone-beam computed tomography image and cast analyses before and after treatment (i.e., outcomes measured), analyzed treatment effects not confounded by additional and concomitant procedures (e.g., surgically-assisted rapid palatal expansion, extractions, and fixed appliances)

The first duplicate articles were excluded from the study. Articles were excluded if they did not meet the inclusion criteria or if they were abstracts, laboratory studies, descriptive studies, case reports, case series, and reviews or meta-analyses. Title and abstract screening were performed by two authors (E.B. and H.S.). Full texts and abstracts of eligible studies were also individually reviewed by them. In addition, any disagreement was resolved by another author (A.M.). The studies with a risk of bias were assessed based on the study design using the Cochrane risk of bias tool for randomized clinical trials (RCTs) or Downs and Black scale for controlled clinical trials (CCTs).

The main outcome measures (i.e., primary dependent variables) were the changes in the transverse dimension based on different landmarks (e.g., apex of teeth, crown of teeth, alveolar bone in different regions, and skeletal changes of maxilla or nasal bone) after treatment using bone-borne or tooth-borne appliances. The secondary outcomes were the changes in the angulation of teeth after treatment. Because of the differences in the treatment modalities, age group, study design, and gender of patients in the base studies, the standardized mean difference and random-effects meta-analysis was performed and if it was possible, subgroup analysis based on the age group, gender, and study design was performed so that the effects of these confounding factors on the outcome measures could be assessed.

Results

Search strategy, date of search, and number of relevant articles for each database can be seen in Table II. After removing duplicates, 186 articles remained out of 304 initial articles. A total of 176 articles were excluded on the basis of title and abstract. Out of the 10 remaining 10 articles, 6 papers were excluded after the evaluation of their full texts (Figure 1). Finally, four studies were selected for meta-analysis (11-14).

Table I. Characteristics of the studies considered for the final analysis

First author (published year)	Journal	Study design	Comparison groups	Sample size	Age: Mean± standard deviation (year)	Gender	Setting	Observation period	Analyzed attributes	Follow-up
Lagraver et al. (2013)	American Journal of Orthodontics and Dentofacial Orthopedics	Randomized clinical trial	Controls; TBE; BBE	Controls (n=21); TBE (n=20); BBE (n=21)	Controls: 12.8±1.19 TBE: 14.05±1.35 BBE: 14.24±1.32	19 M 43 F	Alberta, Canada University of Alberta	18 months	Dental Expansion (M,a&c;PM,a&c;I,a&c); Skeletal Expansion (Al.M;Al.PM;Nas;Max); Dental Angulation (M,L&R;PM,L&R)	No
Lu Lin et al. (2015)	Angle Orthodontist	p Prospective controlled clinical trial	TBE; BBE	TBE (n=13); BBE (n=15)	TBE: 18.1±4.4 BBE: 17.4±3.4	28 F	Seoul, Korea Kyung Hee University	3 months	Dental Expansion (M,a&c;PM,a&c); Skeletal Expansion (Al.M;Al.PM;Nas); Dental Angulation (M,L&R;PM,L&R)	No
Mosleh et al. (2015)	American Journal of Orthodontics and Dentofacial Orthopedics	Prospective controlled clinical trial	TBE; BBE	TBE (n=10); BBE (n=10)	Overall: 12.6±0.6	20 F	Cairo, Egypt Cairo University	11 days	Dental Expansion (M,a&c;PM,a&c); Skeletal Expansion (Al.M;Al.PM;Al.C;Nas;Max;Fac); Dental Angulation (M,L&R;PM,L&R)	No
Yilmaz et al. (2015)	European Journal of Orthodontics	Cohort study	TBE (Banded and bonded); BBE	TBE (Banded) (n=14); TBE (Bonded) (n-=14); BBE (n=14)	TBE (Banded): 12.1±2.1 TBE (Bonded): 13.4±1.7 BBE: 13.2±2.1	22 M 20 F	Ankara, Turkey Başkent University	3 months	Dental Expansion (M,a&c;I,a&c); Skeletal Expansion (Al.M;Nas;Max); FMA; GoGn-SN; ANB	No

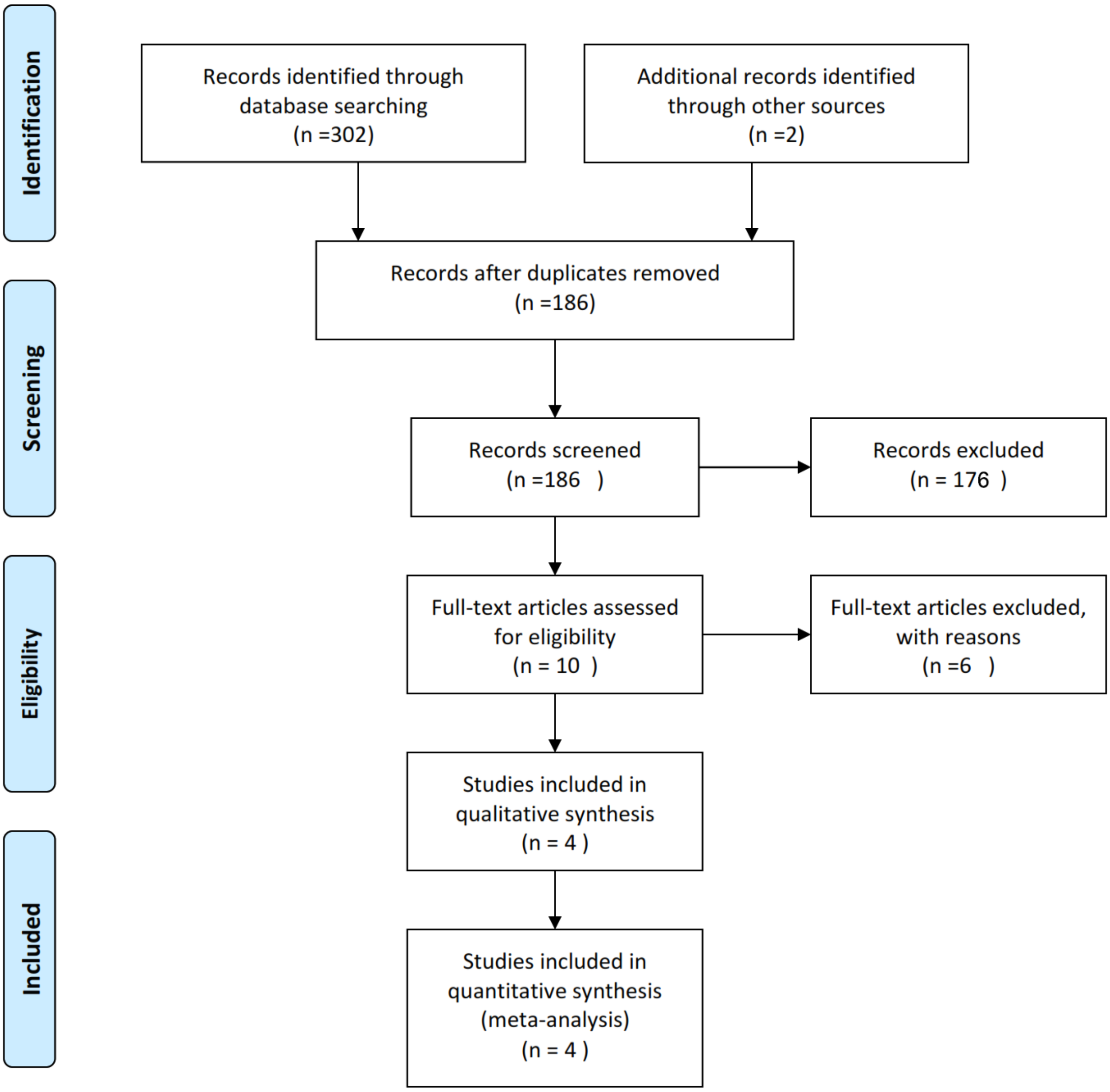

Figure 1. PRISMA flowchart for the evaluated studies

Study characteristics

Study characteristics of the final four trials included in the meta-analysis are summarized in Table I. All selected clinical trials examined treatment results between bone-borne and tooth-borne maxillary expansion appliances in patients who needed maxillary expansion. All the studies were performed in a university setting or an educational institution. The studies consisted of three prospective studies, including one RCT (14), two CCTs (11, 12), and one cohort study (15). The total number of patients treated with BBE appliance was 60, whereas the overall TBE appliance sample consisted of 57 untreated subjects. Two of studies included both male and female participants (13, 14), and the other two included only girls (11, 12).

There was an age discrepancy between the included studies; 3 trials (12-14) had samples with a mean age of 12 to 14 years, and 1 trial (11) included older patients with a mean age of 17 to 18 years. The comparison between appliances was homogeneous among the selected studies: Tooth-borne expander (i.e., banded hyrax with bands on the first premolar and molars) and bone-borne expander (i.e., supported by four TADs in canine-first premolar area and first molar-second premolar area). In one study (13), there was an additional bonded hyrax group, and in another study (14), there was a control group without using any expanders not included in the meta-analysis.

Risk of bias assessment

The only RCT (14) had a low risk of bias (Table II). The risks of bias in other studies (11-13) were scored with medium quality, with the score of 15, 18 and 18 of 32 respectively (Table II), according to the Downs and Black scale. Because of the low number of studies that were included in our study (i.e., lower than 10), the assessment of publication bias using the visual inspection of the funnel plots could not be performed. In addition, the results of the regression test of Egger et al. showed P-values of 0.497 for transverse expansion of alveolar bone in the molar area.

Quantitative data synthesis

After performing the meta-analysis on four studies consisting of 57 patients treated with TBE appliance and 60 patients treated with BBE devices, the standardized mean difference for the treatment effects of these devices on transverse change of molar apices was -0.14 mm (95% CI, -0.55 mm to 0.28 mm; P=0.53; I^2=0%) (Figure 2.A). Also, the standardized mean difference for the transverse changes after treatment for molar crowns was 0.35 mm (95% CI, -0.29 mm to 0.99 mm; P=0.29; I^2=65%). The standardized mean difference for premolar apices was 0.22 mm (95% CI, -0.49 mm to 0.92 mm; P=0.55; I^2=62%) (Figure 2.B). Moreover, for the premolar crowns, the standardized mean difference was 0.63 mm (95% CI, -0.27 mm to 1.53 mm; P=0.17; I^2=74%).

Data synthesis of two clinical trials with 35 bone-borne and 34 tooth-borne appliances showed that the treatment effect of tooth-borne appliances versus bone-borne appliances for the transverse change of incisor crowns was -0.16 mm (95% CI, -0.64 mm to 0.31 mm; P=0.50; I^2=0%). The meta-analysis also demonstrated that in 43 tooth-borne and 46 bone-borne patients in three included trials, the standardized mean difference between the treatment effect of tooth-borne appliance versus bone-borne appliance was 0.04 mm (95% CI, -0.93 mm to 1.01 mm; P=0.94; I^2=79%) for transverse skeletal change in alveolar bone in premolar area (Figure 2.C).

The standardized mean difference for transverse skeletal change in alveolar bone in the molar area between TBE appliance and BBE appliance patients was 0.05 mm (95% CI, -0.60 mm to 0.70 mm; P=0.88; I^2=66%). This finding was obtained from four trials that were analyzed with 60 BBE and 57 TBE patients (Figure 2.D). The analysis of treatment effects on 37 TBE versus 39 BBE patients from three trials was -0.20 mm (95% CI, -0.68 mm to 0.28 mm; P<0.001; I^2=86%) for transverse skeletal change in nasal bone. Regarding the maxillary transverse expansion after the treatment with RPEs, there were no significant standardized mean differences between both groups. The standardized mean difference was -0.05 mm (95% CI, -0.47 mm to 0.37 mm; P=0.81; I^2=0%) from analyzing three trials with 44 patients treated with tooth-borne and 45 subjects treated with bone-borne appliances.

Table II. Consulted databases, applied search strategy, and numbers of retrieved studies

Database of published trials	***Used search strategy***
MEDLINE searched via PubMed on February 3rd 2019 via www.ncbi .nlm.nih.gov/sites	(Palatal Expansion Technique[MeSH Terms]) OR (Hyrax) OR (Rapid Palatal Expansion) OR (Surgically-Assisted Palatal Expansion) OR (Quad Helix) AND (Bone Plates[MeSH Terms]) OR (Tooth-Borne) OR (Tooth-Anchored) OR (Bone-Borne) OR (TAD) OR (Temporary Anchorage Device*) OR (Bone-Anchored) OR (Micro Implant) OR (Mini Screw)
Cochrane Central Register of Controlled Trials searched via the Cochrane Library on February 3rd 2019 via www.thecochranelibrary.com	#1 MeSH descriptor: [Palatal Expansion Technique] explode all trees 146 #2 Hyrax 37 #3 Rapid Palatal Expansion 134 #4 Surgically-Assisted Palatal Expansion 31 #5 Quad Helix 16 #6 MeSH descriptor: [Bone Plates] explode all trees 490 #7 Tooth-Borne 22 #8 Tooth-Anchored 4 #9 Bone-Borne 15 #10 Temporary Anchorage Device 126 #11 Temporary Anchorage Device* 14 #12 Bone-Anchored 62 #13 Micro Implant 99 #14 Mini Screw 54 #15 (#1 or #2 or #3 or #4 or #5) and (#6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14) 23
Databases of dissertations and conference proceedings	*Used search strategy*
International Association of Dental Research searched on February 4th 2019 and 2017 via https://live.blueskybroadcast.com/bsb/client/_new_default.asp	Maxillary Expansion

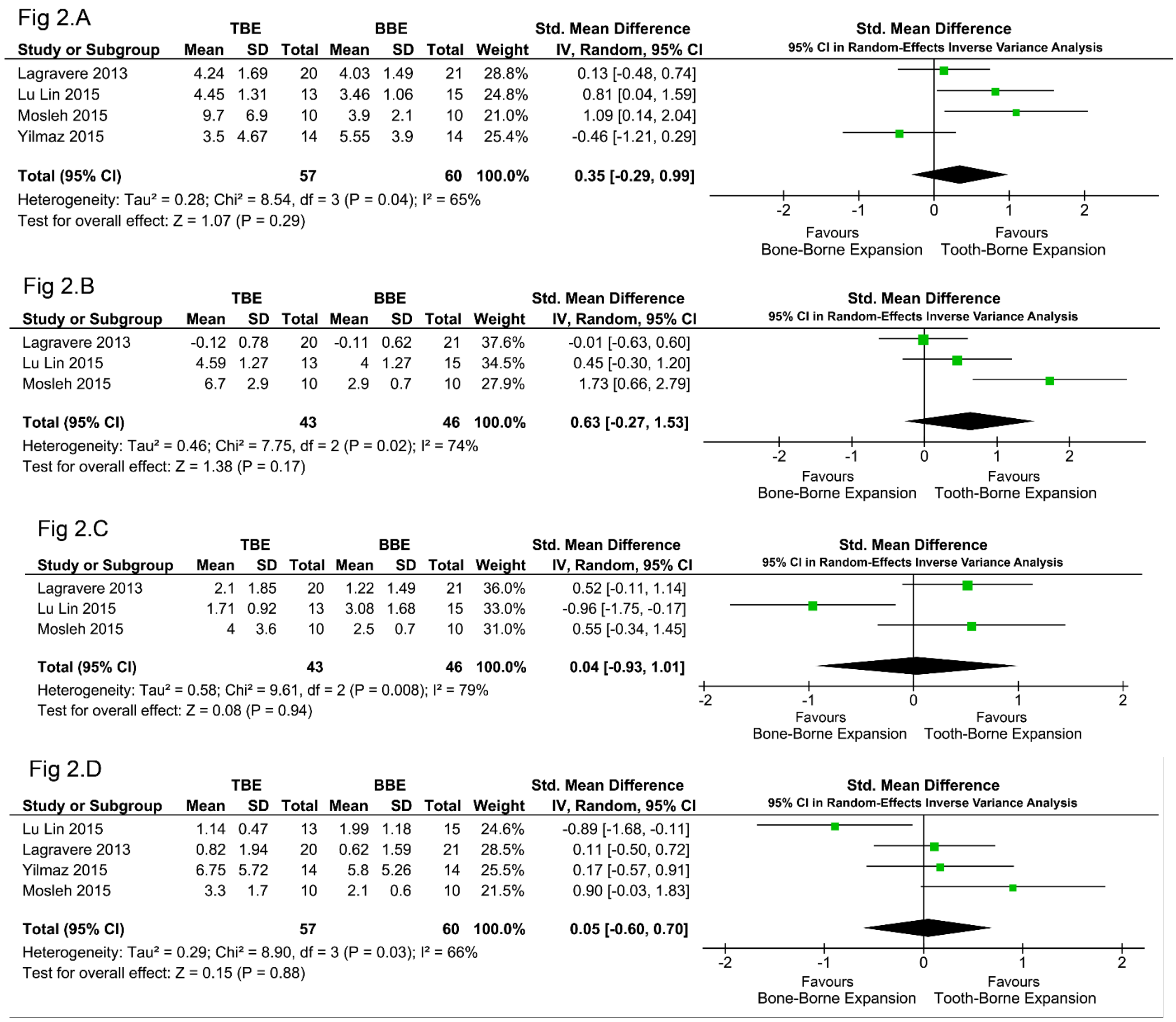

Figure 2. Forest plot depicting the standardized mean difference between the effects of tooth-borne expansion versus bone-borne expansion; A) mean difference for transverse expansion of molar crowns; B) mean difference for transverse expansion of premolar crowns; C) mean difference of the alveolar bone in the premolar area; D) mean difference of the alveolar bone in the molar area

Based on the synthesis of three trials with 43 tooth-borne and 46 bone-borne appliance patients, the standardized mean difference of TBE group relative to the BBE group for the dental angulation of left molars was 0.80 degrees (95% CI, 0.01 mm to 1.59 mm; P=0.05; I^2=67%) (Figure 3.A); for the dental angulation of right molars, it was 0.65 degrees (95% CI, -0.67 mm to 1.94 mm; P=0.33; I^2=88%); for the dental angulation of left premolars, it was 1.69 degrees (95% CI, 1.19 mm to 2.18 mm; P<0.001; I^2=0%) (Figure 3.B); for the dental angulation of right premolars, it was 1.01 degrees (95% CI, 0.11 mm to 1.90 mm; P=0.03; I^2=72%).

Because of the differences in the study designs of the included studies, a sensitivity analysis was conducted based on the study design (i.e., randomized and non-randomized trials). The sensitivity analysis showed no significant differences among the RCT, prospective CCT, and cohort studies regarding the transverse expansion in molars (Chi-square, 0.97; df=1; P=033; I^2=0%) (Fig. 4).

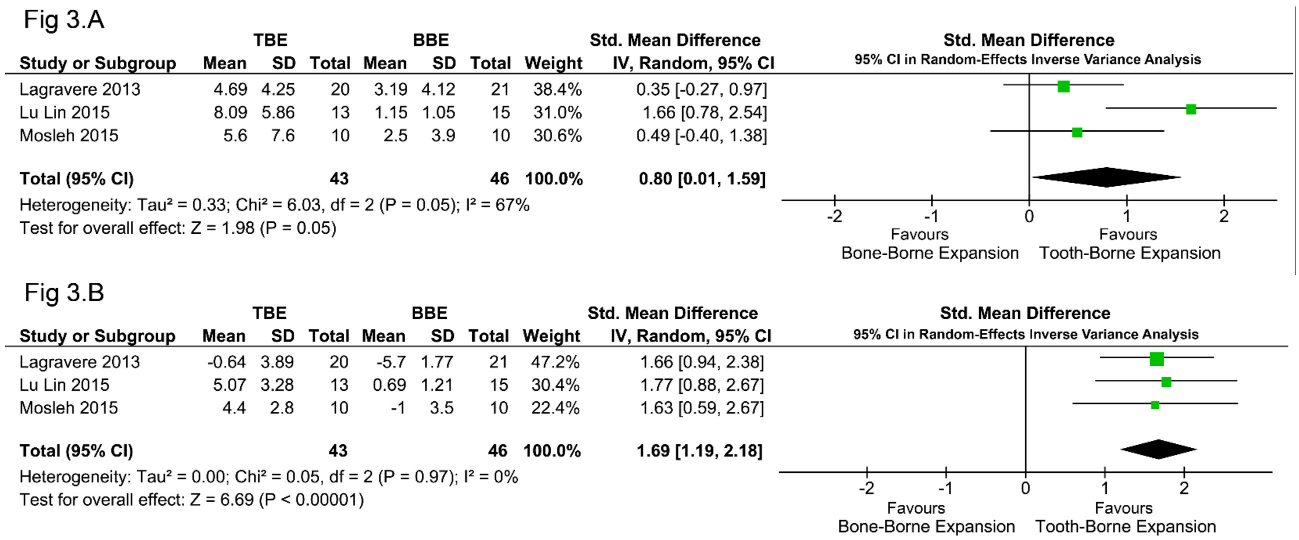

Figure 3. Forest plot depicting the standardized mean difference between the effects of tooth-borne expansion versus bone-borne expansion on dental angulation; A) mean difference for the tipping of the left molars; B) mean difference for the tipping of the left premolars

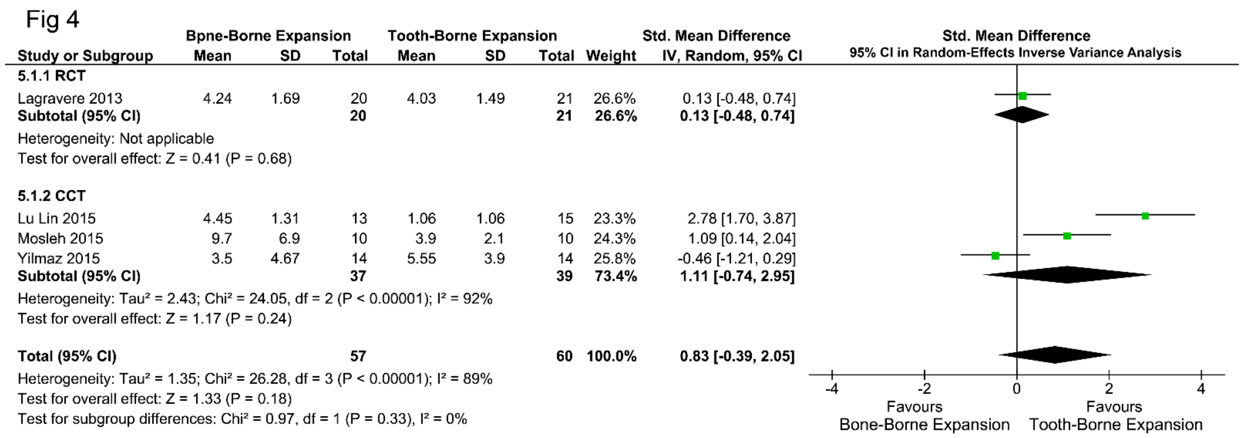

Figure 4. Sensitivity analysis comparing the standardized mean difference of bone-borne expansion and tooth-borne expansion on the molar crown expansion of randomized clinical trial, prospective controlled clinical trials, and cohort studies

Discussion

The results of this meta-analysis showed that bone-borne appliances performed better for the apical expansion of molars that was both clinically and statistically insignificant. However, tooth-borne expander performed better for molar crowns, premolar crowns, and premolar apices with 0.35, 0.63, 0.23 mm higher than standardized mean difference, respectively, compared to bone-borne expanders. The results also showed that there was no clinically or statistically significant difference in the expansion of alveolar bone in molar and premolar areas. Also, no difference in maxillary bone expansion was observed between the two groups. There was more expansion for the nasal bone (i.e., 0.2 mm higher than standardized mean difference) in the BBE group, compared to that in the TBE group, which again is not of clinical importance.

However, the tipping in premolars and molars showed a clinically significant difference with more tipping of teeth in the TBE group (i.e., 3.84 degrees for left molars, 1.52 degrees for right molars, 4.85 degrees for left premolars, and 3.46 degrees for right molars). The biggest problem with this systematic review was the limited amount of evaluated studies. Other problems with this study stem from heterogeneity among the assessed studies and differences in methods and appliances with which the expansions were performed.

The design concepts in some of the appliances (e.g., the use of only two TADs in BBE for Lagravere et al. (14) might have contributed to unexpected results. Standardized mean differences were used to minimize the effects that differences in methods might have had on the results of the outcome measures; nonetheless, the differences in the study design and execution of these studies might lead to imprecisions in the combined results of the base studies. Therefore, it is necessary to perform more high-quality studies with a homogenous and standardized appliance to reach a more concrete conclusion.

The age of the patients at the beginning of treatment in the included trials varied from 12 to 18 years. Therefore, the patients have been studied before, during, and after inter-maxillary suture closure. Inter maxillary suture closure affects the amount and manner of transverse expansion. A subgroup analysis was conducted according to age of the patients at the beginning of treatment comparing treatment before 13 (in studies by Mosleh et al.(12), Yilmaz et al.(13), and Lagravere et al.) and after 13 years of age (in a study by Lin et al.(11).

The 13 years of age was chosen because inter maxillary sutures would begin to close in girls after this age and treatment effects will be influenced. This subgroup comparison indicated no significant differences among the studies (Chi-square, 20.01; df=1; P=0.06; I^2=95%). However, still more high-quality studies with patients in both age subgroups (i.e., over and under 13 years of age) and separate meta-analysis for each age subgroup are needed so that we can reach a higher confidence level in the results of our study.

Conclusion

The BBE appliances in comparison with TBE appliances seem to only have less tipping in their expansion, and other aspects of expansion (i.e., apical and coronal dental expansion and skeletal expansion) seem to be clinically similar between the two appliances. Because of the high level of heterogeneity among studies and low quality of evidence among the included studies, it is recommended to consider the conclusion of this meta-analysis with caution. Moreover, it is required to carry out future high-quality RCTs with a standardized appliance design, similar age groups, and treatment timing to fully clarify the effects of bone-borne rapid maxillary expansion with regards to conventional tooth-borne appliances.

Conflicts of Interest:

The authors declare that there is no conflict of interest.

Acknowledgments

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