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Following Surgically Assisted Rapid Palatal Expansion, Do Tooth-Borne or Bone-Borne Appliances Provide More Skeletal Expansion and Dental Expansion?

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Methods: A computerized database search was performed using PubMed, EBSCO, Cochrane, Scopus, Web of Science, and Google Scholar on publications in reputable oral surgery and orthodontic journals. A systematic review and meta-analysis was then completed with the predictor variables of expansion appliance (TB versus BB) and outcome measure of expansion (in millimeters).

Results: A total of 487 articles were retrieved from the six databases. 5 articles were included, 4 with CBCT data and 1 with non-CBCT 3D cast data. There was a significant difference in the skeletal expansion (SMD = 0.92, 95% CI [0.54, 1.30], $p =$

Conclusion: The literature points to the fact that in order to achieve more effective skeletal expansion and minimize dental expansion after SARPE, a Bone-Borne (BB) appliance should be favored.

Keywords: Bone Borne; Tooth Borne; Rapid Palatal Expansion; SARME; SARPE; Surgically Assisted Rapid Palatal Expansion; Surgically Assisted Rapid Maxillary Expansion.

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Dr. Lee R. Carrasco, DDS, MD

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Bone Borne, Tooth Borne, SARPE, Surgically Assisted Rapid Palatal Expansion, Surgically Assisted Rapid Maxillary Expansion

Subject Categories

Dentistry | Oral and Maxillofacial Surgery | Orthodontics and Orthodontology | Periodontics and Periodontology

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ABSTRACT

Purpose: The aim of this study is to compare the outcome measures of skeletal and dental expansion with Bone-Borne (BB) versus Tooth-Borne (TB) appliances following SARPE. This study is being done to provide quantitative measurements that will help the oral surgeon and orthodontist in selecting the appliance with, on average, the greatest amount of skeletal expansion and the least amount of dental expansion.

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Results: A total of 487 articles were retrieved from the six databases. 5 articles were included, 4 with CBCT data and 1 with non-CBCT 3D cast data. There was a significant difference in the skeletal expansion (SMD = 0.92, 95% CI [0.54, 1.30], $p = <0.001$), in favor of BB appliances, when comparing BB and TB appliances. However, there was not a significant difference in the dental expansion (SMD = 0.05, 95% CI [-0.24, 0.34], $p = 0.03$).

Conclusion: The literature points to the fact that in order to achieve more effective skeletal expansion and minimize dental expansion after SARPE, a Bone-Borne (BB) appliance should be favored.

Keywords: Bone Borne; Tooth Borne; Rapid Palatal Expansion; SARME; SARPE; Surgically Assisted Rapid Palatal Expansion; Surgically Assisted Rapid Maxillary Expansion.

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DETAILED PICO QUESTION

(P) – Patients treatment planned to undergo SARPE

When framing your research question, the (P) applies to the population, the patient or the problem that you are addressing. The most important characteristic of this particular population is a maxillary transverse deficiency. This is the minimum requirement needed to undergo a SARPE procedure. In this systematic review, it was clear that investigating patients undergoing SARPE was the appropriate population. There had been systematic reviews describing the difference between bone-borne (BB) and tooth-borne (TB) expanders in a non-surgical setting. However, differences with SARPE had not been described in a systematic way and so it was clear that this was a population worth investigating. Part of the reason that SARPE studies have not been considered up to this point is the assumption that pure skeletal expansion is anticipated with SARPE. This is not accurate as dental expansion still occurs and, therefore, the proper appliance for maximum skeletal expansion and minimum dental expansion needs to be investigated.

(I) – The intervention included SARPE with a BB appliance placed pre-operatively

When investigating the (I), one must describe the main intervention or exposure that we are considering. The intervention considered here, SARPE with BB appliances, is meant to aid in correcting the patient's maxillary transverse discrepancy. The procedure itself (SARPE) will separate the segments and the intervention (BB appliance) will slowly separate the segments

to get the proper healing pattern. Many examples of BB appliances exist but the literature has been limited to several types. This fact will help, as it will keep heterogeneity as low as possible. Temporary Anchorage Device (TAD) expanders, which are BB expanders, are newly popular in the market and will be making their way into the literature in the future.

(C) – The comparator included SARPE with a TB appliance placed pre-operatively

When investigating the (C), one must describe the main comparator to the intervention mentioned above. The comparator considered here, TB appliances, are meant to aid in correcting the patient's maxillary transverse discrepancy with a Hyrax or something similar. Most studies use Hyrax style expanders when they deciding on a TB appliance. However, when looking through papers and deciding which ones to include, the comparator is a place that one must be very picky. In many studies, the comparator is not well described and the data is not well presented. This could be a major cause of exclusion of the study and must be explained in the flow chart.

(O) – The outcome from the retrieved studies, comprised of variables (a) skeletal expansion, (b) dental expansion (subgroup analysis of premolar and molar expansion also performed for skeletal and dental expansion)

In terms of the (O), the primary outcome variables considered in this study were skeletal and dental expansion. It is understood that each study will have a slightly different interpretation of what those terms mean. This can lead to vastly different

landmarks and, therefore, higher levels of heterogeneity. Therefore, stringent guidelines must exist to ensure that data sets for expansion are not skewed severely. Subgroup analysis data will also be included to compare expansion in the premolar and molar regions. Anterior expansion has not been included as publications do not generally publish that data in their studies.

INTRODUCTION

Surgically Assisted Rapid Palatal Expansion (SARPE) or Surgically Assisted Rapid Maxillary Expansion (SARME) is a surgical technique developed to correct transverse discrepancies in skeletally mature patients.¹ SARPE is indicated in adults to overcome the resistance of ossified sutures, a normal process that occurs during adulthood.² SARPE is generally performed early in the treatment, after orthodontic decompensation of both arches has occurred.³ Under general anesthesia, a Le Fort I osteotomy is performed in conjunction with a midpalatal osteotomy, palatal distractor setting, and a release of the nasal septum.³

The overall treatment plan requires collaboration between an oral surgeon and an orthodontist.⁴ The appliance activated after surgery depends on the preference of the practitioners. A Bone-Borne (BB) appliance, like the Transpalatal Distractor (TPD; Surgitech, Belgium), can be anchored to the palate in order to get the expansion required. Many studies have used the TPD appliance or a similar appliance, such as the Uni-Smile Distractor (Titamed, Belgium) or the MWD device (Normed, Germany), with great results.^{6,7} A tooth-borne (TB) appliance, the Hygienic Appliance for Rapid Expansion (Hyrax) was introduced by Dr. William Biederman in 1968.⁸ Many studies have also shown great results with the Hyrax,^{9,10} but skepticism remains, as studies evaluate its apparent dentoalveolar effects.¹¹

The purpose of this study was to provide quantitative measurements that will help the oral surgeon and orthodontist in selecting the appliance with, on average, the greatest

amount of skeletal expansion and the least amount of dental expansion. The aim of this study is to compare the outcome measures of skeletal and dental expansion, in millimeters (mm), with Bone-Borne (BB) and Tooth-Borne (TB) appliances. The null hypothesis is that there is no difference between Tooth-Borne (TB) and Bone-Borne (BB) appliances when it comes to skeletal and dental expansion after SARPE.

MATERIALS AND METHODS

Study Design, Sample, Variables

To address the research purpose and aim, the investigators designed and implemented a systematic review. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines were observed in preparation of this systematic review.

The PICO strategy has been employed in this systematic review. **(P)** - The patient study sample included patients treatment planned to undergo SARPE **(I)** - The intervention included SARPE with a BB appliance placed pre-operatively. **(C)** - The comparator included SARPE with a TB appliance placed pre-operatively. **(O)** - The outcome from the retrieved studies, comprised of variables (a) skeletal expansion, (b) dental expansion (subgroup analysis of premolar and molar expansion will also be performed for skeletal and dental expansion)

In different terms, the predictor variables include patients undergoing SARPE with BB appliances versus SARPE with TB appliances. The outcome variables include skeletal and dental expansion, measured in millimeters.

Data Collection Methods

A computerized database search was performed using PubMed, EBSCO, Google Scholar, Cochrane, Scopus, and Science Direct up to May 25, 2016. The study

population was composed of all publications on the topic between 1950 to 2015. There were commonalities in the search terms, but the combination of terms inputted in each database was dependent on the database presented in Table 1. Main search terms were included in Table 1 but customized searches were also done to include terms such as “Hyrax”, “Haas”, “MWD”, and “Transpalatal Distractor”. These searches terms were not included in Table 1 as studies within these customized search terms were included in the search terms of Table 1. Manual computerized searches were also performed in a plethora of journals related to the subject; a summary of the journals searched has been included in Table 2. The searches were conducted by two researchers individually. Also, the reference sections of the articles searched in the 6 databases were screened for additional pertinent studies. The Google Scholar search was performed to overcome possible publication bias. Papers that were included were segmented into two distinct tracks, one with CBCT data and one without. The tracks were included because there is a possible improved case assessment and management with CBCT versus without.¹² This is a concept that needs further investigation and will be discussed more at length in the discussion. Track 1 were human trials where the indications for SARPE were clearly stated, specific emphasis was placed on BB appliances versus TB appliances, CBCT was used to analyze the data, and the outcome measures were skeletal expansion and dental expansion. Track 2 were human trials where the indications for SARPE were clearly stated, specific emphasis was placed on BB appliances versus TB appliances, CBCT was not used to analyze the data, and the outcome measures were skeletal expansion and dental expansion. Papers were included if they were from peer-reviewed journals, human

studies, published from 1950 to 2015, and groups were clearly defined (comparing the stated intervention and comparator). Papers were excluded if the publications were letter to editors, case reports, uncontrolled case series, conference proceedings, abstracts, and any non-English article (with no available English full text).

PubMed	Results
((surgically assisted rapid palatal expansion OR surgically assisted rapid maxillary expansion OR SARPE OR SARME) AND tooth borne AND bone borne)	37
CINAHL (EBSCO since 1999)	Results
((surgically assisted rapid palatal expansion OR surgically assisted rapid maxillary expansion OR SARPE OR SARME) AND tooth borne AND bone borne)	51
Google Scholar	Results
"surgically assisted rapid palatal expansion" "tooth borne" "bone borne"	152
Cochrane Library	Results
(surgically assisted rapid palatal expansion OR surgically assisted rapid maxillary expansion OR SARPE OR SARME) AND tooth borne AND bone borne	7
Scopus	Results
((surgically assisted rapid palatal expansion OR surgically assisted rapid maxillary expansion OR SARPE OR SARME) AND tooth borne AND bone borne)	26
Web of Science	Results
((surgically assisted rapid palatal expansion OR surgically assisted rapid maxillary expansion OR SARPE OR SARME) AND tooth borne AND bone borne)	214

Table 1. The final Boolean search keywords used in the present systematic review, organized by database. Last search update May 25th, 2016. None of the selected keywords were included in MESH Terms database.

Journals Included in Manual Searches
Journal of Oral and MaxilloFacial Surgery (JOMS)
British Journal of Oral and Maxillofacial Surgery (BJOMS)
International Journal of Oral & Maxillofacial Surgery (IJOMS)

Journal of Cranio-Maxillo-Facial Surgery (JCMFS)
Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology (OOOO)
Oral and Maxillofacial Surgery (ISSN: 1865-1550)
Journal of Maxillofacial and Oral Surgery (ISSN: 0972-8279)
Egyptian Journal of Oral & Maxillofacial Surgery
Annals of Oral & Maxillofacial Surgery (UK)
Face, Mouth & Jaw Surgery (UK)
Oral and Maxillofacial Surgery Clinics

Table 2. A list of the journals included in manual search. The search engine of each journal was consulted on its webpage.

Quality Assessment

Once the articles included in the review were identified and reviewed, the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies (QATQS) (<http://www.ephpp.ca/tools.html>) was used to assess the quality of the available evidence.¹³ EPHPP QATQS has content/construct validity and excellent inter-rater reliability.¹³ QATQS consists of six criteria (selection bias, study design, confounders, blinding, data collection method, and withdrawals) each of which can be rated as strong, moderate, or weak according to a specific definition in the QATQS dictionary.¹³ Studies with no weak rating and four strong ratings were classified as “strong;” studies with more than one weak rating were classified as “weak;” and studies with only one weak rating or less than four strong ratings were classified as “moderate.”¹³ The two first authors independently assessed the quality of the included studies and any discrepancies were resolved by discussion and consensus. Kappa statistics was used to assess inter-rater agreement on the quality assessment results.

Primary Outcome Variables

The primary outcome variables in the included studies could be categorized into two groups:

1. Skeletal

Landes et al. calculated skeletal expansion by subtracting external and internal maxillary width measurements.¹⁴ The width between the tooth apices on the palatal root of the premolars and molars was taken pre-operatively and post-expansion.¹⁴ Significance ($p < 0.05$) was found when comparing BB and TB in the premolar region but not in the molar region.¹⁴ Nada et al. and Zandi et al. used a similar method to calculate skeletal expansion; using the distance between the palatal root apices.^{15,16} In both the Nada and Zandi studies, no significance was found between groups in the premolar or molar regions.^{15,16} Seeberger et al. also calculated molar apex width, however, using mesiobuccal apices.¹⁷ No significance was observed between the BB and TB groups, at both the premolar and molar regions.¹⁷ Koudstaal et al. calculated skeletal expansion by measuring the depth of the palate at the level of the gingival margin on 3D casts, both at the premolar and molar levels.¹⁸ A significant increase was seen, at both the premolar and molar levels.¹⁸

2. Dental

Landes et al. calculated dental expansion by using internal maxillary width measurements.¹⁴ The width between the lingual cusp tips of the premolars and molars was taken pre-operatively and post-expansion.¹⁴ No significance ($p > 0.05$) was found in the premolar region and the molar region, when comparing BB and TB appliances.¹⁴

Nada et al. and Zandi et al. used a similar method to calculate dental expansion; using the distance between the lingual cusp tips.^{15,16} In both the Nada and Zandi studies, no significance was found between groups in the premolar or molar regions.^{15,16} Seeberger et al. also calculated dental expansion, however, using distance between the middle of the pulp chamber of each premolar and molar.¹⁷ No significance was observed between the BB and TB groups in the premolar region but statistical significance was observed in the molar region.¹⁷ Koudstaal et al. measured dental expansion from the tip of the buccal cusp of the premolars and the tip of the disto-buccal cusp of the first molar.¹⁸ No significance was observed between the BB and TB groups in the premolar and molar regions, making expansion parallel in the PA plane.¹⁸

Confounding Variables

Confounding variables in this study were organized into several categories. Demographic variables that were confounding include age, skeletal age, gender, and race. Pre-operative variables included hemi/bimaxillary discrepancy, CBCT voxel size, when the CBCT was take, and the measurement tools/software used. Peri-operative procedures were also considered confounding including if 2 piece/3 piece SARPE were done. Lastly, post-operative orthodontics was confounding including what measurement tools/software was used, amount of expansion/day, and the consolidation time for each study sample.

Data Analyses

The outcome measures of this study were continuous outcomes (skeletal expansion and dental expansion), so the analytical statistics of standardized mean difference (SMD) at 95% confidence intervals (95% CIs) were used to determine the effectiveness of the BB appliance compared to TB appliance for both skeletal expansion and dental expansion. The I^2 statistic and Chi-square test of heterogeneity were used to assess the statistical heterogeneity of the included studies. Values of $I^2 > 50\%$ or $P < 0.10$ were considered high heterogeneity numbers across studies. When heterogeneous results were high, the total SMD score at 95% CI was calculated using a random-effects model; otherwise, a fixed-effects model was used. Subgroup analysis was then performed taking into account premolar and molar positions. To assess the degree of publication bias, funnel plots and Egger's tests were used. Stata 11.0 (College Station, Texas 77845 USA) was used to implement the meta-analysis.

RESULTS

Overview

A total of 487 articles were retrieved from the six databases. The duplicates were then removed, leaving a total of 326 articles. The articles were then screened on the basis of title and abstract and 269 articles were excluded. The final 57 articles were screened by manuscript review and application of inclusion criteria. 52 articles were excluded for the included reasons: BB appliance is the main focus of the study, TB appliance is the focus of the study, main focus of the study is not BB and TB appliances, the study was not performed on human subjects, the study was unrelated to SARPE, the outcome variable was not a part of PICO of this study, and the article was not available in the English language. Track 1 and 2 were then split to give four studies in Track 1 and one study in Track 2. A flow diagram summary of the database searches has been provided in Figure 1. Quality assessment criteria were then completed on the included studies. The study of *Zandi et al.* was of “moderate” quality while the other four studies were deemed to be of “weak” quality. The criteria most likely to be “weak” in the overall “weak” quality studies were withdrawals and blinding. The Kappa = 1.000; SE of kappa = 0.000; the strength of agreement was considered “perfect”.

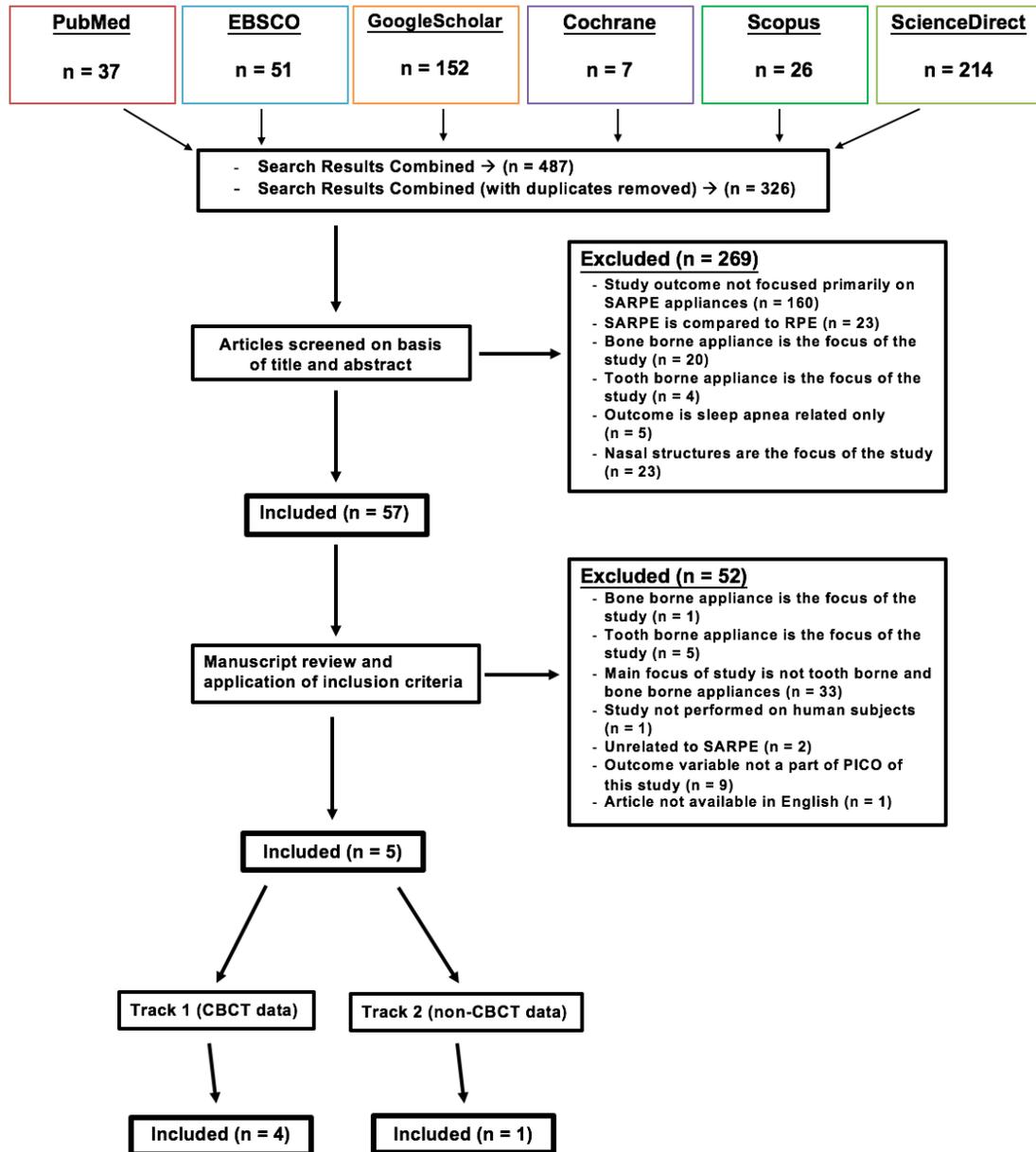


Figure 1. Flow Diagram from the six database searches

The systematic review included a total of 204 patients. The age and gender distribution, when included, is summarized in Table 3 and 4. Each study had 2 groups, one with BB appliances and one with TB appliances. Track 1 data was included in Table 3 and Track 2 data was included in Table 4. When statistical analysis was

completed, all of the data was grouped together for both the CBCT (Track 1) and non-CBCT (Track 2) papers.

Author Year Journal Design	Patients Gender Age Range	Group (n, mean age) Appliance	Latency Expansion Consolidation	CBCT Voxel Size Time Taken	Skeletal Expansion (mm)		Dental Expansion (mm)		Quality Weak Mod Strong
					Premolar (1 st Premolar)	Molar (1 st Molar)	Premolar (1 st Premolar)	Molar (1 st Molar)	
Landes et al. 2009 J Craniofac Surg Retrospective and Prospective	n = 50	Group I (n =24) = Bone-Borne appliance (MWD device; Germany) Group II (n =26) = Tooth-Borne appliance (Hyrax device; Germany)	5 days 0.5-0.6 mm/ day Not specified	Not specified 1. Pre-op 2. After expansion	Group I = 6.51 +/- 3.19 Group II = 3.42 +/- 1.69	Group I = 3.19 +/- 1.87 Group II = 3.87 +/- 4.04	Group I = 7.51 +/- 3.30 Group II = 5.52 +/- 2.44	Group I = 7.12 +/- 2.29 Group II = 5.87 +/- 2.36	Weak
Nada et al. 2012 J Craniomaxillofac Surg Prospective Cohort	n = 45 17 M / 28 F	Group I (n = 17; 29.4 yrs) = Bone-Borne appliance (Transpalatal Distractor; Belgium) Group II (n = 28; 24.5 yrs) = Tooth-Borne appliance (Hyrax device; Germany)	7 days 1 mm/day 3 months	0.4 mm 1. Pre-op 2. After orthodonti c treatment	Group I = 5.20 +/- 3.20 Group II = 4.60 +/- 2.30	Group I = 4.60 +/- 3.00 Group II = 4.58 +/- 2.90	Group I = 6.95 +/- 3.20 Group II = 7.03 +/- 3.50	Group I = 6.77 +/- 3.55 Group II = 5.64 +/- 2.90	Weak
Zandi et al. 2014 J Craniomaxillofac Surg RCT	n = 30 11 M / 19 F 15 – 27 yrs	Group I (n = 13; 20.3 yrs) = Tooth-Borne appliance (Hyrax device; Germany) Group II (n = 15; 19.4 yrs) = Bone-Borne appliance (Transpalatal Distractor; Belgium)	7 days 0.5-0.6mm/ day 4 months	0.4 mm 1. Pre-op 2. After consolidat ion	Group I = 5.38 +/- 2.01 Group II = 4.40 +/- 1.68	Group I = 4.81 +/- 2.09 Group II = 4.50 +/- 1.83	Group I = 7.23 +/- 2.77 Group II = 6.73 +/- 2.15	Group I = 7.12 +/- 2.87 Group II = 6.53 +/- 2.67	Mod
Seeberger et al. 2015 OOOO Retrospective	n = 33 14 M / 19 F	Group I (n =19; 22 yrs) = Bone-Borne appliance (Titimed Uni-Smile Distractor; Belgium) Group II (n =14; 30 yrs) = Tooth-Borne appliance (Hyrax device; Germany)	5-7 days 0.5 mm/day 3 months	Not specified 1. 1m pre- op 2. After consolidat ion	Group I = 3.30 +/- 3.10 Group II = 3.30 +/- 3.40	Group I = 3.20 +/- 2.80 Group II = 2.45 +/- 3.32	Group I = 4.60 +/- 3.4 Group II = 5.55 +/- 5.23	Group I = 3.40 +/- 2.40 Group II = 5.45 +/- 4.45	Weak

Table 3. Information extracted from the four included CBCT studies

Author Year Journal Design	Patients Gender Age Range	Group (n, mean age) Appliance	Latency Expansion Consolidation	Impressions Time	Skeletal Expansion (mm)		Dental Expansion (mm)		Quality
					Post (1 st Premolar)	Posterior (1 st Molar)	Posterior (1 st Premolar)	Posterior (1 st Molar)	Weak Mod Strong
Koudstaal et al. 2009 Int J. Oral	n = 46 23 M / 23 F 16 – 50 yrs	Group I (n = 25) = Bone-Borne appliance	7 days 1 mm/day 3 months	1. Pre-op	Group I = 2.90 +/- 2.20	Group I = 2.60 +/- 2.50	Group I = 7.00 +/- 3.50	Group I = 4.60 +/- 3.10	Weak

Table 4. Information extracted from the one included non-CBCT studies (3D cast)

Meta-Analysis

There was heterogeneity ($I^2 > 50\%$, $P < 0.10$) in both dental and skeletal expansion; so, the random-effects model was used across the board. Considering the pooled effect size data, there was a significant difference in the skeletal expansion (SMD = 0.92, 95 % CI [0.54, 1.30], $p = < 0.001$), in favor of BB appliances, when comparing BB and TB appliances (Figure 2). However, there was not a significant difference in the dental expansion (SMD = 0.05, 95 % CI [-0.24, 0.34], $p = 0.03$) (Figure 3). The funnel plot for the dental expansion was symmetrical indicating publication bias is unlikely (Figure 4). The funnel plot for skeletal expansion demonstrated a small asymmetry, indicating an unlikely, but small, possibility of publication bias (Figure 5). In addition, sub-group analysis of premolar and molar expansion, demonstrated that using BB appliances were more effective in skeletal expansion than TB appliances at both premolar (SMD = 0.93, 95 % CI [0.27, 1.60], $p = < 0.001$) and molar levels (SMD = 0.92, 95 % CI [0.41, 1.44], $p = < 0.001$) (Table 5). However, in dental expansion, there was no significant difference between BB appliances and TB appliances at both premolar (SMD = 0.07,

95 % CI [-0.30, 0.45], $p = 0.13$) and molar (SMD = 0.02, 95 % CI [-0.46, 0.49], $p = 0.02$) levels (Table 5).

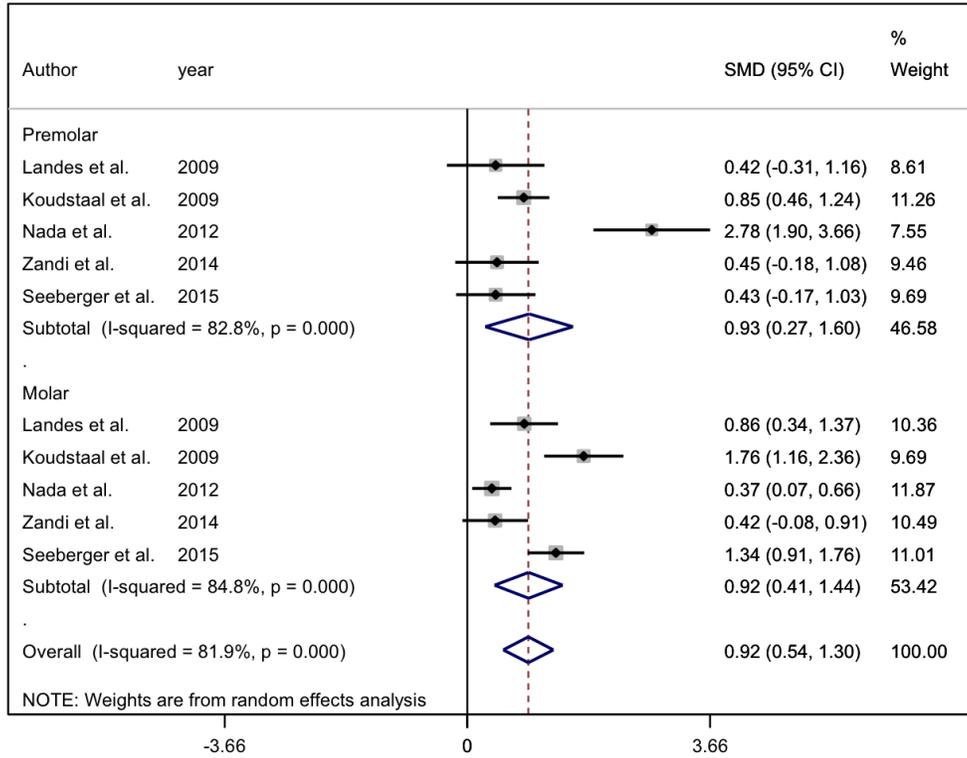


Figure 2. The forest plot for skeletal expansion, comparing BB and TB appliances.

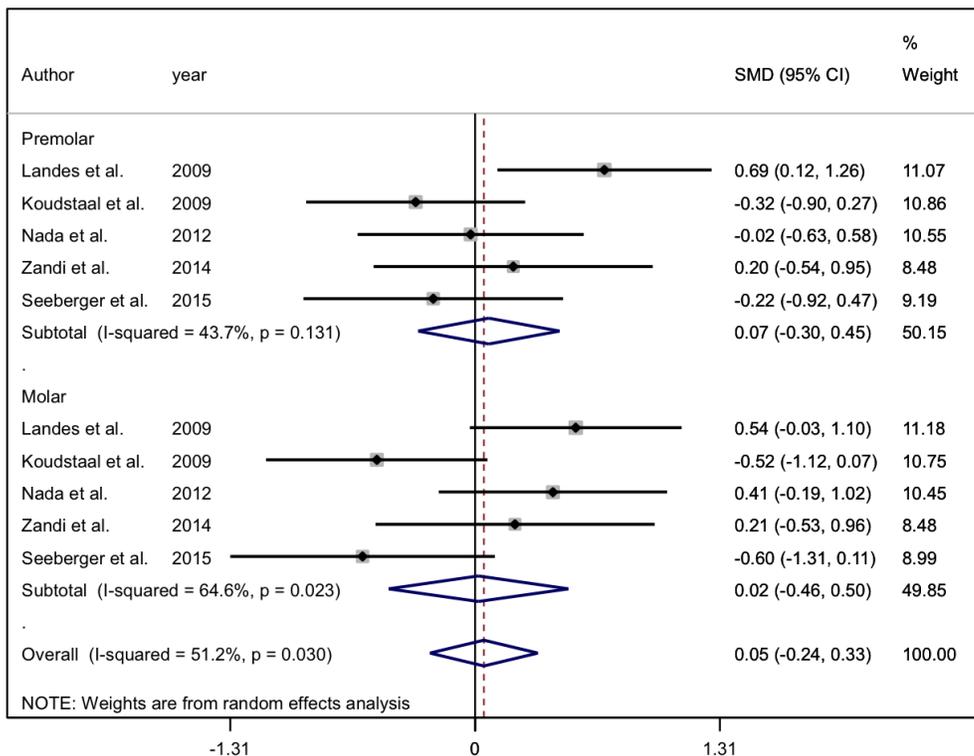


Figure 3. The forest plot for dental expansion, comparing BB and TB appliances

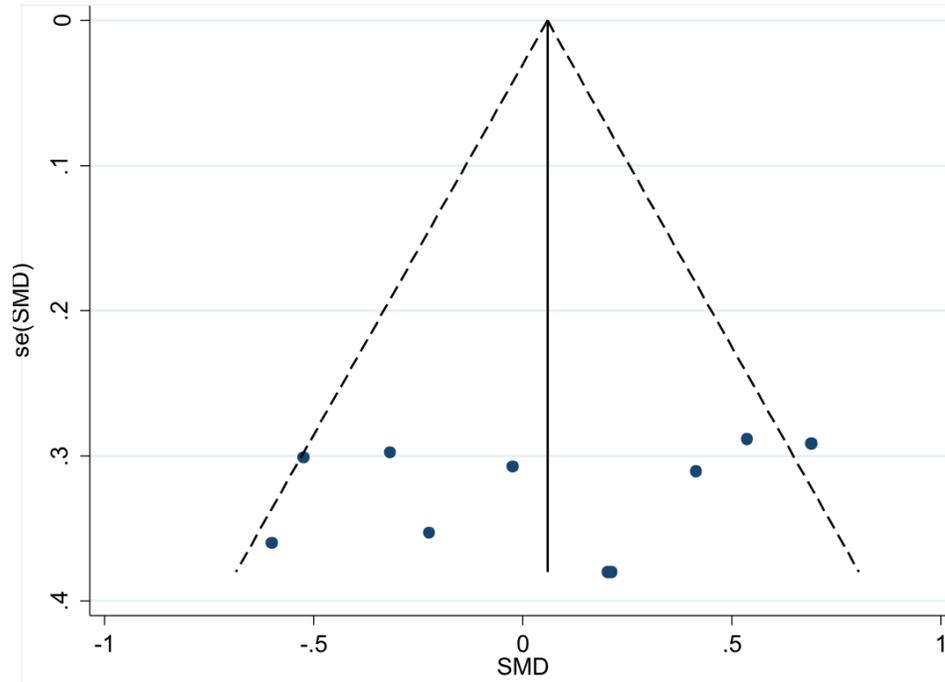


Figure 4. The funnel plot for dental expansion

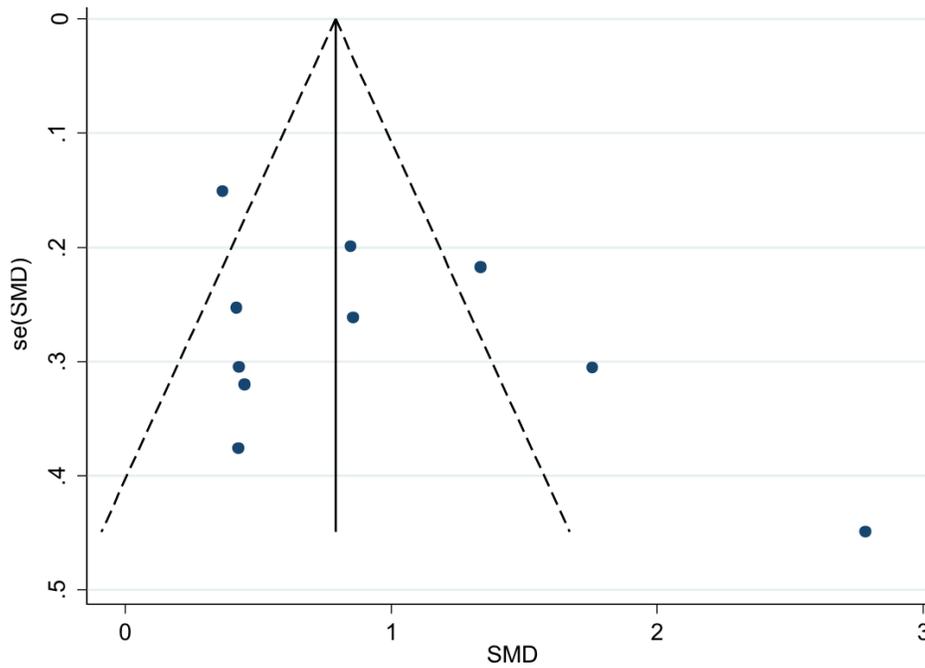


Figure 5. The funnel plot for skeletal expansion.

Comparison groups	No. of studies	Summary estimates of mean difference (95%CI)	I ² %	Heterogeneity test		Egger test	
				Q	P	t	P
Comparison groups							
Skeletal Expansion	10	0.92 (0.54, 1.30)	81.9	49.65	<0.001	1.50	0.17
Dental Expansion	10	0.05 (-0.24 , 0.34)	51.2	18.46	0.03	-0.75	0.47
Dental Expansion							
Molar	5	0.02 (-0.46 , 0.49)	64.6	11.31	0.02	-0.55	0.62
Premolar	5	0.07 (-0.30 , 0.45)	43.7	7.1	0.13	-0.35	0.75
Skeletal Expansion							
Molar	5	0.92 (0.41, 1.44)	84.8	26.38	<0.001	1.60	0.21
Premolar	5	0.93 (0.27 , 1.60)	82.8	23.21	<0.001	0.65	0.56

Table 5. Skeletal and Dental Expansion of BB and TB appliances at both premolar and molar levels

DISCUSSION

Overview

The purpose of this study was to provide quantitative measurements that will help the oral surgeon and orthodontist in selecting the appliance with, on average, the greatest amount of skeletal expansion and the least amount of dental expansion. The aim of this study is to compare the outcome measures of skeletal and dental expansion, in millimeters (mm), with Bone-Borne (BB) and Tooth-Borne (TB) appliances. The null hypothesis is that there is no difference between Tooth-Borne (TB) and Bone-Borne (BB) appliances when it comes to skeletal and dental expansion after SARPE.

Decision Making Process

Each paper included in this systematic review and meta-analysis began with the purpose of differentiating skeletal and dental expansion. This was achieved with landmarks on CBCT and 3D casts. The reason that the distinction between skeletal and dental expansion needs to be made is due to the potential dentoalveolar effects of many appliances. The goal, post SARPE, is to minimize the potential dentoalveolar effects and maximize the skeletal effects with the expander appliance. A patient is going under a surgical procedure in order to correct a skeletal transverse discrepancy, as such the appliance must work towards maximum correction. Based on the meta-analysis provided in this paper, the more sensible appliance to use would be a BB appliance during and after SARPE has been completed. The BB device will lead to significant increase in skeletal expansion and non-significant increase in dental

expansion. Many point towards the hygienic benefit of the TB appliance as a means of justifying its use, which is sensible in certain clinic situations. The goal of this meta-analysis was to provide the reader with a statistical evaluation of the effects of each appliance on skeletal expansion, which is the ultimate goal of this surgical procedure. It was to also provide the practitioner a more objective way of making a decision. Although many considerations are included when selecting appliances, the goal should always be to achieve the greatest amount of effect from the appliance per use. All signs point towards BB appliances achieving that greatest amount of effect skeletally, while avoiding significant dentoalveolar effects. The results of this study match what other studies have speculated about the skeletal effects of the BB appliance, and dentoalveolar effects of the TB appliance.¹¹ The BB and TB appliance might not be so different in dental expansion but the BB is significantly better at skeletal expansion.^{14,18}

Strengths and Limitations

There were strengths and weaknesses to this systematic review. Strengths include the use of CBCT in most of the included studies, the preparation of a meta-analysis for the data set, the strict inclusion and exclusion criteria, and the meticulous database and hand searches completed. However, there were several limitations that were observed during the culmination of this systematic review and meta-analysis. Regarding the quality assessment, it is not common in dental and maxillofacial literature to mention the details of randomization, blinding, or dropouts in the manuscript. Therefore, this leads to lower quality assessment ratings, thereby many times underestimating the true quality of the paper. This could negatively affect the interpretation of the this study's

results. Moreover, the high level of heterogeneity among methodology in SARPE papers limits the number of papers included in these types of reviews. Detailed and comprehensive inclusion and exclusion criteria will usually yield a small number of results. For this reason, papers with CBCT data (Track 1) and non-CBCT data (Track 2) were included in the statistical analysis together. Further studies should focus on formulating data with CBCT only in order to grow the body of literature in this specific area. In addition, lack of proper long term follow up in these patients leaves questions about the stability of the different appliances. A paper with a comprehensive number of follow up numbers will increase the quality of the results of the present systematic review and meta-analysis. Lastly, analysis of this kind with anterior expansion would be advantageous. Many papers excluded or did not calculate canine level expansion in the CBCT studies.

CONCLUSIONS

The literature points to that fact that in order to achieve more effective skeletal expansion and minimize dental expansion after SARPE, a BB appliance should be favored. Further controlled clinical studies with CBCT are needed to further prove this conclusion and also determine the retention of skeletal and dental expansion in BB versus TB appliances.

REFERENCES

1. Lima SM Jr., de Moraes M, Asprino L. Photoelastic analysis of stress distribution of surgically assisted rapid maxillary expansion with and without separation of the pterygomaxillary suture. *J Oral Maxillofac Surg* 2011;69:1771-5
2. Laudemann K, Santo G, Revilla C, et al: Assessment of surgically assisted rapid maxillary expansion regarding pterygomaxillary disjunction using thin volume-rendering technique: In variance analysis and in reliability, accuracy, and validity. *J Oral Maxillofac Surg.* 2011;69:2631
3. Betts NJ, Vanarsdall RL, Barber HD, Higgins-Barber K, Fonseca RJ. Diagnosis and treatment of transverse maxillary deficiency. *Int J Adult Orthod Orthognath Surg* 1995;10:75-96
4. Kennedy JW 3rd, Bell WH, Kimbrough OL, et al. Osteotomy as an adjunct to rapid maxillary expansion. *Am J Orthod* 1976;70:123-137
5. Mommaerts, M Y. Transpalatal Distraction as a Method of Maxillary Expansion. *British journal of oral and maxillofacial surgery.* 1999;37(4):268–272.
6. Nowak, Rafal & Zawiślak, Ewa. The Analysis of Early Changes to Craniofacial Skeleton Induced by Transpalatal Distraction in a Patient with Maxillary Constriction, Based on Computed Tomography Scans – Case Report. *Dental and Medical Problems.* 2016;53:134-141.
7. Seitz O, Landes CA, Philipp DJ, Sader R, Klein CM. Reliable surgically assisted rapid palatal expansion by maxillary widening device. *J Craniofac Surg.* 2008;19(3): 846–9
8. Biederman W. A hygienic appliance for rapid expansion. *J Pract Orthod* 1968;2(2):67-70
9. Bays RA, Greco JM. Surgically assisted rapid palatal expansion: an outpatient technique with long-term stability. *J Oral Maxillofac Surg* 1992;50(2):110-113
10. Schimming R, Feller KU, Herzmann K, et al. Surgical and orthodontic rapid palatal expansion in adults using Glassman's technique: retrospective study. *Br J Oral Maxillofac Surg* 2000;38(1):66-69
11. Oliveira NL, Da Silveira AC, Kusnoto B, Viana G. Three-dimensional assessment of morphologic changes of the maxilla: A comparison of 2 kinds of palatal expanders. *Am J Orthod Dentofacial Orthop.* 2004;126:354–62.

12. Naini, Farhad, Gill Daljit. Orthognathic Surgery: Principles, Planning, and Practice. John Wiley & Sons.
13. Armijo-Olivo S, Stiles CR, Hagen NA, et al: Assessment of study quality for systematic reviews: A comparison of the Cochrane Collaboration Risk of Bias Tool and the Effective Public Health Practice Project Quality Assessment Tool: Methodological research. *J Eval Clin Pract* 2012;18:12
14. Landes CAC, Sygouros A, Motro M, Ugurlu F, et al: Surgically The Journal of craniofacial surgery: Comparison of tooth- and bone-borne devices in surgically assisted rapid maxillary expansion by three-dimensional computed tomography monitoring: transverse dental and skeletal maxillary expansion, segmental inclination, dental tipping, and vestibular bone resorption. *Lippincott Williams and Wilkins*; 2009;20:1132.
15. Nada, R. M., Fudalej, P. S., Maal, T. J. J., Bergé, S. J., Mostafa, Y. A., & Kuijpers-Jagtman, A. M. Three-dimensional prospective evaluation of tooth-borne and bone-borne surgically assisted rapid maxillary expansion. *Journal of Cranio-Maxillofacial Surgery*. 2012;40(8):757-762.
16. Zandi, M., Miresmaeili, A., & Heidari, A. Short-term skeletal and dental changes following bone-borne versus tooth-borne surgically assisted rapid maxillary expansion: A randomized clinical trial study. *Journal of Cranio-Maxillofacial Surgery*. 2014;42(7):1190-1195.
17. Seeberger, R., Abe-Nickler, D., Hoffmann, J., Kunzmann, K., & Zingler, S. One-stage tooth-borne distraction versus two stage bone-borne distraction in surgically assisted maxillary expansion (SARME). *Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology*. 2015;120(6):693-698.
18. Koudstaal, M., Wolvius E., Schulten A., Hop W., van der Wal K. (2009). Stability, tipping and relapse of bone-borne versus tooth-borne surgically assisted rapid maxillary expansion; a prospective randomized patient trial. *International Journal of Oral and Maxillofacial Surgery*. 2009;38:308-315.