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Review article

Evaluation of pterygomaxillary disjunction on skeletal and dental changes after surgically assisted rapid maxillary expansion: A systematic review and meta-analysis

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ABSTRACT

Background: Surgically assisted rapid maxillary expansion (SARME) with disjunction of the pterygomaxillary suture is a procedure widely used in maxillofacial surgery. However, the pterygomaxillary disjunction (PD) procedure has often been deemed risky. The actual necessity and effectiveness of PD in SARME remain subjects of debate, with some studies suggesting that sufficient expansion can be achieved without it. This systematic review with meta-analysis aimed to evaluate the scientific literature regarding the effects of PD on skeletal and dental changes after SARME.

Methods: The systematic review followed the Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to identify relevant articles published in different databases. The study conducted a comprehensive literature search across seven databases: PubMed/Medline, Web of Science, Science Direct, Scopus, Embase, Cochrane Collaboration Library, and Google Scholar. The selected studies evaluated the effect of the extent of expansion and the stability of SARME with PD, as well as the skeletal and dental changes associated with the treatment. The intervention cohorts within the sampled population chosen for incorporation into our analysis consisted of individuals who underwent SARME accompanied by PD, whereas the control group underwent SARME devoid of PD. Data were combined in a meta-analysis using the Review Manager 5.3.5. (RevMan) program. A systematic search was performed in seven databases (PubMed/Medline, Web of Science, Science Direct, Scopus, Embase, Cochrane Collaboration Library, and Google Scholar).

Results: After applying the selection criteria, seven articles were included in the systematic review, totaling 291 patients. Five articles were selected for meta-analysis. A meta-analysis was conducted to assess the effects of anterior and posterior dental expansions. After applying the selection criteria, seven articles were included in the systematic review, totaling 291 patients. Five articles were selected for meta-analysis. A meta-analysis was conducted to assess the effects of anterior and posterior dental expansions. Expansion in the previous region was slightly higher in the SARME with PD group compared to the PD-free group (95 % CI: 1.07 to 1.1 mm; $p = 0.98$). In the posterior region, expansion exceeding 0.11 mm was observed in the SARME with PD group compared to the PD-free group, but without statistical significance (95 % CI: 1.64 to 1.86 mm; $p = 0.903$).

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Conclusion: SARME combined with PD proves to be an effective surgical procedure for correcting transverse maxillary deficiencies. However, no statistically significant differences were observed when SARME with and without PD was compared, indicating that SARME with PD can be used especially in cases that require expansion in the posterior region of the maxilla.

1. Introduction

The maxilla shows a distinct behavior during human development, exhibiting anteroposterior growth during bone remodeling, a process consisting of the resorption of old bone and deposition of new bone. Horizontal growth of the maxillary arch occurs through remodeling of the maxillary tuberosity. These bones are connected by cartilaginous tissue that is later replaced with mineralized tissue. The midpalatal suture is located in the anteroposterior direction, joining the base of the skull with the facial skeleton, and is responsible for the growth of the maxilla in the transverse direction [1,2].

To achieve ideal occlusion, the upper dental arch needs to be proportionally larger than the lower dental arch, so that the palatal cusps of the upper premolars and molars adapt properly to the occlusal fossae of the lower premolars and molars [3,4]. Treatments involving malocclusions are often associated with transverse maxillary deficiencies, which manifest clinically as unilateral or bilateral crossbite, a narrow nasal cavity, arch length discrepancy, and speech and swallowing problems [5,6]. Rapid maxillary expansion is a therapeutic approach used to treat this condition in patients during the phase of development. The technique is based on using orthodontic/orthopedic appliances or surgical procedures that promote disjunction of the midpalatal suture and pterygomaxillary sutures [7].

Treatments using dental expanders have advantages in terms of expansion of the maxillary arch, enlargement of the nasal cavity, and anterior movement of the maxilla. However, this type of treatment is associated with some complications [8,9], such as root resorption, gingival recession, marginal bone loss, reduced buccal bone thickness, and bone fenestration [10–12]. The failure rates of rapid maxillary expansion are related to resistance to expansion and pain during the procedure, causing high rates of recurrence [2, 13].

In skeletally mature adult patients, the exclusive use of orthodontic/orthopedic appliances to promote rapid maxillary expansion is not appropriate due to fusion of the midpalatal and pterygomaxillary sutures. Thus, other procedures such as surgically assisted rapid maxillary expansion (SARME) have been used to improve treatment outcomes [12,14]. This type of expansion is an effective method to treat maxillary deficiencies, showing less morbidity. The therapeutic protocol is based on the combination of orthodontic procedures and different surgical techniques that promote enlargement of the dental arch and tooth alignment [15,16]. In summary, SARME typically involves osteotomies like the Le Fort I technique, combined with disjunction of the mid-palatal suture, optionally with pterygomaxillary disjunction (PD). Following this, a palatal distractor is inserted into the patient's oral cavity. This distractor may be affixed to the patient's posterior teeth (tooth-borne distractor), directly to the maxilla (bone-borne distractor), or a combination of both (hybrid distractor) [12–16].

Currently, there remains a lack of consensus within the literature regarding the optimal osteotomies for Surgically Assisted Rapid Maxillary Expansion (SARME). Resistance areas have been categorized into anterior support (piriform aperture pillars), lateral support (zygomatic buttresses), posterior support (pterygoid junctions), and median support (midpalatal synostosed suture). Consequently, surgical procedures may entail Le Fort I osteotomy combined with other specific osteotomies, including: 1) PD; 2) median palatal suture osteotomy; and 3) two paramedian osteotomies between the lateral incisor and the canine. To ensure the selection of the most effective treatment, guaranteeing predictable and stable results, minimizing patient morbidity, and avoiding long-term complications and relapse, further elucidation on maxillary osteotomies for SARME is imperative [17,18]. Segmented Le Fort I osteotomy can be performed to separate the maxilla by SARME, which will release the maxillary bones and palatal suture with or without disjunction of the pterygoid processes, promoting lateral repositioning of the parts and correction of the transverse deficiency. Another technique is partial maxillary osteotomy, which uses an expander to reduce the resistance to maxillary expansion. However, this type of procedure has limitations related to the location of anatomical structures that offer greater resistance to expansion, such as the pterygoid processes [17,18].

To the best of our understanding, this represents the inaugural systematic review incorporating a meta-analysis, assessing skeletal and dental effects in individuals with PD undergoing SARME treatment. Within this context, the aim of this systematic review was to evaluate the findings regarding the effects of PD on skeletal and dental changes after SARME.

2. Material and methods

2.1. Ethical considerations

Since this systematic review analyzed secondary literature data, Ethics Committee approval was not necessary. The study is registered in the International Prospective Register of Systematic Reviews (PROSPERO) under number CRD42020210719.

2.2. Databases and identification of studies

The systematic review was conducted following the Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)

guidelines to identify relevant articles in the following databases: PubMed/Medline, Web of Science, Science Direct, Scopus, Embase, Cochrane Collaboration Library, and Google Scholar were used to conduct time-free searches for publications through Jan 9, 2023. The reference lists of the retrieved articles were hand searched to identify potentially relevant studies for inclusion in the systematic review.

2.3. Formulation of the research question (PICO)

The PICO strategy was adopted for formulation of the research question: P = population (adult patients diagnosed with transverse maxillary changes); I = intervention (SARME with PD); C = comparison (comparison of pre- and postoperative data in which the patient serves as his/her own control); O = outcome (skeletal/dental changes resulting from the surgical procedure).

2.4. Eligibility criteria

Clinical studies evaluating SARME with PD were included in the systematic review. To be eligible, the selected studies should assess the effect of the extent of expansion and the stability of SARME with PD, as well as skeletal and dental changes associated with the treatment. There were no restrictions on publication year or language. No exclusions based on age, type of malocclusion, or the specific type of anchorage appliance used were applied.

Two reviewers independently selected the studies retrieved by the literature search. First, titles and abstracts were analyzed and articles considered to be relevant were selected. Next, the reviewers read the full text of the selected articles and classified them according to the risk of bias. Disagreements were resolved by consensus to ensure the quality of the review process. Articles that met all established eligibility criteria were included in the present systematic review.

2.5. Search strategy

The search strategy was based on combinations of the following search terms: Pterygomaxillary dysjunction [Mesh]; Pterygomaxillary separation [Mesh]; (Pterygomaxillary separation [Mesh] OR Pterygomaxillary dysjunction [Mesh]) AND Assisted Rapid Maxillary [Mesh]; (Pterygomaxillary separation [Mesh] OR Pterygomaxillary dysjunction [Mesh]) AND Skeletal Changes [Mesh]; (Pterygomaxillary separation [Mesh] OR Pterygomaxillary dysjunction [Mesh]) AND Dental Changes [Mesh]; (Pterygomaxillary separation [Mesh] OR Pterygomaxillary dysjunction [Mesh]) AND Skeletal AND Dental Changes [Mesh]. Details of the search keys used in each database are available in Supplementary File 1.

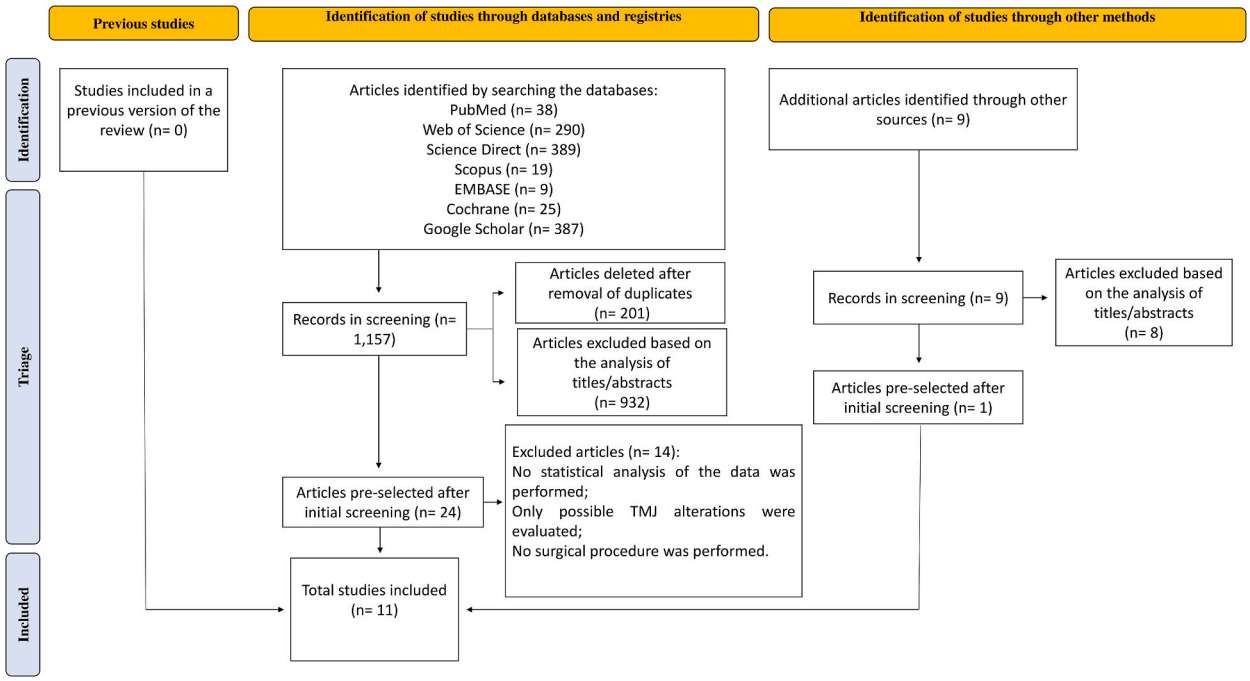

Fig. 1. Flow diagram of the article screening and selection process.

2.6. Data extraction

Two reviewers independently extracted the data from the included studies. Disagreements were resolved by discussion and consensus. Data were entered into an Excel spreadsheet. The data analyzed encompassed various aspects, including the study design, demographic details of the studied population, the surgical procedures performed, measurements of dental and skeletal expansion, criteria utilized for evaluating the results, and the follow-up.

2.7. Risk of bias assessment and analysis of the quality of evidence

To provide reliable evidence, all included articles were submitted to a critical review. For this purpose, the criteria of the Methods Guide for Comparative Effectiveness Reviews, developed by the American Agency for Healthcare Research and Quality [19], were applied. The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was used to analyze the quality of the studies [20].

2.8. Meta-analysis

After assessment of the risk of bias and quality of the selected articles, the methodological homogeneity of the studies and the possibility of conducting a meta-analysis using current literature data were evaluated. If possible, the data were combined in a meta-analysis using the Review Manager (RevMan) 5.3.5. program developed by the Cochrane Collaboration (2014).

3. Results

3.1. Characteristics of the sample

The electronic search in the different databases retrieved 1166 studies. After the initial screening of titles and abstracts and removal of duplicates, the full text of 25 articles was read. The articles were analyzed according to the inclusion and exclusion criteria and 11 studies were included in the present systematic review [9,21–30] Fig. 1 shows the flow diagram of the selection and inclusion of the studies. All selected studies were submitted to risk of bias and quality assessment (Table 1 and Supplementary File 2, respectively). Nearly all the studies we selected demonstrated a low risk of bias, indicating a robust methodological approach in their designs and executions. However, it's important to note that the study conducted by Ribeiro Prado et al. stood out with a moderate risk of bias [26].

Ten of the 11 articles included in the systematic review were randomized clinical trials [9,21–25,27–30] and one was a retrospective study [26]. A total of 291 participants were included, with the sample consisting mainly of female patients and young adults. SARME with PD was performed in all cases. Seven studies also performed rapid maxillary expansion without PD and compared the two treatments [9,21,22,24,25,27,28].

3.2. Expansion device and protocol of expansion screw activation

The Hyrax appliance was the main expansion device used [9,23,24,26,30]. The protocol of expansion screw activation is described in Supplementary 2.

Table 1
Risk of bias assessment in the selected studies.

Author	Year	Study design	Randomized sample?	Inclusion and exclusion criteria described?	Follow-up time reported?	Have the measures analyzed been described?	Statistical analysis performed?	Risk of Bias
Han et al. [21]	2006	Clinical trial	Yes	Yes	Yes	Yes	Yes	Low
Vasconcelos et al. [22]	2006	Clinical trial	Yes	Yes	Yes	Yes	Yes	Low
Loddi et al. [23]	2008	Clinical trial	Yes	Yes	Yes	Yes	Yes	Low
Laudemann et al. [24]	2009	Clinical trial	Yes	Yes	Yes	Yes	Yes	Low
Kilic et al. [25]	2013	Clinical trial	Yes	Yes	Yes	Yes	Yes	Low
Ribeiro Prado et al. [26]	2013	Retrospective	No	Yes	Yes	Yes	Yes	Moderate
Sygouros et al. [27]	2014	Clinical trial	Yes	Yes	Yes	Yes	Yes	Low
Zandi et al. [28]	2014	Clinical trial	Yes	Yes	Yes	Yes	Yes	Low
Ferraro-Bezerra et al. [9]	2018	Clinical trial	Yes	Yes	Yes	Yes	Yes	Low
Karabiber et al. [29]	2019	Clinical trial	Yes	Yes	Yes	Yes	Yes	Low
Kayalar et al. [30]	2009	Clinical trial	Yes	Yes	Yes	Yes	Yes	Low

3.3. Main musculoskeletal and dental changes observed after rapid maxillary expansion with pterygomaxillary disjunction

Clinical trials have sought to identify the patterns of dentoskeletal changes that occur after SARME with and without PD. Ferraro-Bezerra et al. [9] evaluated two surgical techniques (SARME with and without PD) and compared dentoskeletal changes using cone beam computed tomography. In that study, all measurements increased significantly between T0 and T1 in both groups. Mean expansion of the Hyrax appliance was 6.2 ± 0.4 mm in the SARME without PD group and 5.8 ± 0.4 mm in the SARME with PD group. The authors did not find significant differences between the groups with and without PD; however, greater palatal expansion was observed in the SARME with PD group and greater dental expansion in the molar region occurred in the group without PD. At the end of the follow-up period, almost all bone and dental measures in the anterior region were higher in the SARME without PD group compared to the group with PD, except for maxillary width and the degree of canine inclination.

Zandi et al. [28] who evaluated SARME with PD and subdivided the patients according to the type of anchorage device (dental or bone) found comparable dental and skeletal changes after the procedure in both groups. The overall complication rate of the two

Table 2
Overview of the full-text studies included in the systematic review, describing the study design, characteristics of the participants, intervention, and results.

Study (year)	Method	Participants	Intervention	Major results
Han et al. [21]	Randomized clinical trial	18 (F: 12; M: 6)	Group I: Treated with Le Fort I osteotomy, including PD and anterior median palatine osteotomy. Group II: Treated with Le Fort I osteotomy, without PD.	The results suggest that SARME without pterygomaxillary separation allows relatively equal expansion in the area of the anterior teeth, while the expansion in the posterior and interdental maxillary regions were acquired more efficiently with the expansion of the maxilla by the SARME with PD.
Vasconcelos et al. [22]	Randomized clinical trial	10 (F: 5; M: 5)	Group I: SARME with PD. Group II: SARME without PD.	There were no statistically significant differences between the groups.
Loddi et al. [23]	Randomized clinical trial	40 (F: 20; M: 20)	All patients were treated with Le Fort I osteotomy, including PD. Twenty patients were treated with Hyrax expander and 20 with Haas expander.	The opening of the median palatine suture in patients who used SARME with PD is greater with Hyrax devices (69.2 %) than with Haas (60 %).
Laudemann et al. [24]	Randomized clinical trial	65 participants	Group I: SARME with PD. Group II: SARME without PD.	SARME with PD produced a greater segmental tilt in the anterior-posterior direction in patients with assistive devices. SARME without PD in patients <20 years and SARME with PD in patients >20 years produced the greatest expansion in the posterior region. PD should be based on the patient's age and individual needs, i.e., in patients <20 years (SARME-DP) and >20 years (SARME + DP).
Kilic et al. [25]	Randomized clinical trial	18 (F: 16; M: 2)	Group I: SARME without PD. Group II: SARME with PD.	All cross-sectional measures increased after expansion in the groups that underwent MSSA with PD. Both SARME techniques resulted in significant maxillary expansion.
Ribeiro Prado et al. [26]	Retrospective	30 (F: 12; M: 18)	30 adults undergoing SARME with PD.	SARME with PD and SARME without PD are reliable methods to obtain maxillary expansion, with small differences in the patterns of skeletal and dental changes.
Sygouros et al. [27]	Randomized clinical trial	20 (F: 16; M: 4)	Group I: SARME with PD. Group II: SARME without PD.	SARME with or without PD is an effective technique to treat maxillary transverse deficiency in adolescent and adult patients. Pterygomaxillary disjunction is recommended in patients with periodontal involvement.
Zandi et al. [28]	Randomized clinical trial	30 (F:19; M: 11)	SARME with PD.	The dental and skeletal effects of dental and bone devices were comparable. The overall complication rate was negligible. The selection of an expansion device should be based on the requirements of each patient.
Ferraro-Bezerra et al. [9]	Randomized clinical trial	24 (F:18; M: 6)	Group I: SARME without PD; Group II: SARME + PD	SARME with PD and SARME without PD are reliable methods for obtaining maxillary expansion.
Karabiber et al. [29]	Randomized clinical trial	16 (F: 8; M: 8)	Unilateral SARME with PD and separation of the median palatine suture.	The mechanics of the treatment had no clinically harmful effects on the alveolar bone and was considered effective in cases with posterior crossbite.
Kayalar et al. [30]	Randomized clinical trial	20 (F:11; M: 9)	Group I: SARME with PD with the use of a dental support device (Hyrax; Forestadent, Pforzheim, Germany). Group II: SARME with PD using a hybrid dental and bone device.	Skeletal and soft tissue nasal parameters increased significantly in the T0 and T1 and T0 and T2 periods in both groups. No statistically significant differences were observed between the groups. The mean width of the piriform opening increased significantly after the surgical procedure in both groups. In soft tissue, the width of the alar base increased to 2.78 mm and the alar width to 2.95 mm.

Legends: SARME, Surgically assisted rapid maxillary expansion; PD, Pterygomaxillary disjunction; M, male; F, female.

treatment modalities was negligible. According to the authors, each technique has its advantages and disadvantages and the distraction device for SARME should be selected based on the needs of each patient.

According to Kilic et al. [25] SARME with PD results in greater posterior expansion than the procedure without PD. In that study, all transverse measurements increased after expansion in the group with PD. Expansion at the midpalatal and gingival level was greater in the group without PD, while the group with PD showed an increase of 0.78 mm at the level of the apical base and 11.25° less inclination in molar teeth. Expansion was about 0.7 mm greater in the region of the premolars in the group with PD. In a longitudinal study, Ribeiro Prado et al. [26] observed a significant increase in palatal measurements at 4 months compared to preoperative values, with $p < 0.05$ in patients undergoing SARME with PD. However, there was no significant difference at 10 months compared to the 4-month follow-up ($p > 0.05$).

Sygouros et al. [27] reported SARME to be effective in increasing the transverse dimension in the groups with and without PD, with no differences between groups. According to the authors, SARME with or without PD is an effective technique to treat transverse maxillary deficiencies in adolescent and adult patients. However, PD should be recommended in patients with periodontal involvement because the results of Sygouros et al. [27] indicate that SARME without PD leads to significant additional tension in the periodontal apparatus of patients, especially in the region of the premolars, reducing the buccal alveolar bone dimension and alveolar ridge width and height when compared to SARME with PD. Loddi et al. [23] reported the success of SARME with PD and found that the Hyrax appliance promoted greater opening of the palatal suture in the anterior (67 %) and posterior (70 %) regions than the Haas appliance in the same regions. Table 2 summarizes the main results of the selected studies.

3.4. Meta-analysis

Meta-analysis evaluating anterior and posterior dental expansions was possible in five studies [9,21,22,24,27]. In the previous region, expansion was found to be 0.01 mm greater in the SARME with PD group compared to the group without PD (95 % confidence interval: 1.07 to 1.1 mm). The p-value for this difference was 0.98. In the posterior region, expansion greater than 0.11 mm was found in the SARME with PD group, with a 95 % confidence interval of −1.64 to 1.86 mm, when compared to the group without PD ($p = 0.903$). The results are illustrated in Fig. 2.

4. Discussion

The aim of the present systematic review was to evaluate the effects of SARME combined with PD on skeletal and dental changes. We specifically evaluated the transverse maxillary expansion potential of SARME combined with PD, comparing pre- and post-operative data, and compared the results between groups undergoing SARME with and without PD.

Previous systematic reviews have evaluated the role of SARME [31,32]. However, although the pterygomaxillary region has been commonly included during SARME procedures, the disjunction of this important anatomical area has rarely been the focus of studies evaluating these procedures. Although some authors found an increased risk of transoperative bleeding after SARME combined with PD [33], other studies reported significant clinical benefits of PD, including increased expansion of the posterior palatal region, opening of the midpalatal suture [9], and significant increases in nasopharyngeal and oropharyngeal volumes [34].

The main methods used to evaluate maxillary expansion and its effects on posterior crossbite are dental models [25,35–38], conventional cephalometric analysis [36,38–40], posteroanterior cephalograms [41,42], and computed tomography [9,24,27,28].

Several studies aimed to identify the role of PD in the success rate of maxillary atresia treatment. Pereira et al. [43] evaluated the effects of PD in patients with anterior, posterior, and anteroposterior maxillary atresia. In the case of anteroposterior atresia, the authors performed subtotal Le Fort I osteotomy with PD, while subtotal Le Fort I osteotomy without PD and subtotal Le Fort I osteotomy with PD were used for anterior and posterior atresia, respectively. Although comparison of computed tomography scans of midpalatal suture openings obtained before surgery and immediately after the completion of activation revealed promising results, comparison with a control group to evaluate the effect of PD versus treatment without PD in each case was not reported. Han et al. [21] concluded that SARME with or without PD promotes relatively equal expansion in the anterior and posterior regions and is an effective treatment method. On the other hand, de Assis et al. [44] who used the finite element method to evaluate the effect of PD, found that a combination of Le Fort I osteotomy and PD promotes greater expansion and less stress in the maxillary region. Our meta-analysis did not show significant differences between SARME with and without PD, indicating that both techniques were effective.

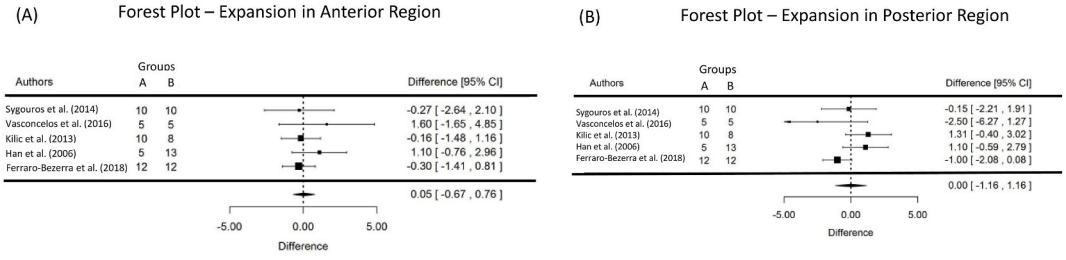

Fig. 2. Forest plot. (A) Anterior region. (B) Posterior region.

Iodice et al. [40] studied 21 patients undergoing SARME with PD and evaluated palatal inclination of the upper incisors using three cephalometric measurements: 1-NA (°) was statistically significant, indicating dental inclination in the posterior region, while 1-SN (°) and 1-FH (°) did not show significant results. In the case of any maxillary expansion (whether orthopedic or surgical), enlargement of the maxillary arch perimeter after the creation of a diastema is often used to correct dental crowding or to retract proclined incisors. Mundstock et al. [45] found a 9.7-degree change in inclination after rapid maxillary expansion with the Hyrax appliance.

Studies evaluating positional changes of the maxillomandibular complex by three-dimensional analysis may provide more reliable clinical results. However, both the assessment and the outcome can be compromised by the heterogeneity of the data [46]. The combined use of two-dimensional and three-dimensional methods, as done in the present study, generates results that correlate with other variables and provides valuable information for the field of three-dimensional cephalometric analysis. Since mandibular changes after SARME with PD can affect the clinical and esthetic outcome, special attention is required during surgical planning and after completion of the expansion phase [47]. Knowledge of these effects related to individual treatment planning based on the dentofacial characteristics of each patient is necessary to maximize functional esthetic gains.

The main limitation of this systematic review with meta-analysis was the lack of standardization of the craniofacial and dental measurements in the included studies. The only similarity across the literature was changes in intercanine and intermolar distances. There is no standardized measure for the detection of skeletal, alveolar, and periodontal changes (expansion) after SARME. Furthermore, most of the studies did not perform long-term follow-up. Future studies should take these limitations into account and should conduct a more detailed analysis of the available data in order to better understand the role of PD.

Our meta-analysis suggests that the expansion potential of SARME in terms of anterior and posterior dental expansion does not differ when the procedure is performed with or without PD. However, SARME combined with PD proved to be a safe and effective technique.

5. Conclusion

SARME combined with PD is an effective surgical procedure for correcting transverse maxillary deficiencies. However, no statistically significant differences were observed when SARME with and without PD was compared, indicating that the latter is not a mandatory step to achieve satisfactory maxillary expansion in all cases but can be used especially in cases that require expansion in the posterior region of the maxilla. More controlled clinical studies are needed to determine the potential benefits and complications of SARME combined with PD.

CRediT authorship contribution statement

Luís Eduardo Charles Pagotto: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Everton Freitas de Morais:** Writing – original draft, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **Gabriel Pires Pastore:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Informed consent

For this type of study informed consent is not required.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication

For this type of study consent for publication is not required.

Data availability statement

Data included in article/supp. material/referenced in article:

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e38872.

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