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Alar width changes due to surgically-assisted rapid palatal expansion: A meta-analysis

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Abstract:

A major objective of orthognatic surgery is the aesthetic outcome. Treatments only correcting for dentoskeletal deformities are not sufficient for optimal facial results because undesirable soft tissue changes may accompany skeletal manipulations. The primary objective of this study was to investigate alar base width (ABW) changes a minimum of 6 months following surgically-assisted rapid palatal expansion (SARPE). The following electronic databases and citation indices were searched: PubMed, Cochrane Library, Scopus, Web of Science, Embase, and Virtual Health Library. The search included articles published until September 2015 without language restriction. The intervention was SARPE with maxillary vestibular incision from first molar to contralateral first molar, a modified LeFort I osteotomy with or without pterygomaxillary disjunction, and a V-Y closure. The primary outcome was the unstandardized mean difference between pre and postoperative ABW. A random effects meta-analysis was performed to combine study results, and included studies that were assessed for statistical heterogeneity using a Chi-square test for independence. The results of this meta-analysis ($N = 41$) showed a significant + 1.74 mm, 95% CI [0.14, 3.34] ABW increase in patients submitted to SARPE. There was no statistical heterogeneity among included studies ($\chi^2 = 0.03$; df = 2; $P = 0.98$). ABW increases were observed despite including cinched patients in the analysis. None of the three included studies were completely free of bias. The most prominent flaws were measurement bias, limited sample size, and patient recruitment.

Keywords:

Alar width, meta-analysis, surgical palatal expansion

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Introduction

Maxillary transverse deficiencies produce a variety of clinical sequelae including crowded maxillary dentition, posterior crossbites, overly wide buccal corridors, and nasal airway obstruction.[1] Both surgical[2,3] and nonsurgical treatment[1,4,5] modalities exist to correct these maxillary arch insufficiencies. Nonsurgical treatment via orthodontic therapy is often indicated in patients yet to reach skeletal maturity.[5] On the other hand, surgery is often indicated in skeletally mature patients whose ossified sutures are resistant to forced orthopedic movement.[3] Surgically-assisted rapid palatal expansion (SARPE) is a treatment option for skeletally mature patients with significant maxillary arch discrepancy.[2,3] While the effectiveness of SARPE as a corrective treatment has been well-documented,[2,6-8] it has also been associated with postoperative changes in the surrounding soft tissues, most notably widening of the nasolabial complex.[9-11] Although authors disagree about the ability of orthopedic maxillary expansion alone to widen the alar base,[9,12,13] there remains the possibility that nasolabial soft tissue migration following SARPE is a function of both: (1) muscular foreshortening from subperiosteal dissection and (2) osseous base expansion at the anterior piriform aperture.

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Full thickness maxillary vestibular incisions sever periosteal attachments causing affected muscles to shorten and retract laterally. These secondary changes manifest as flattening and thinning of the upper lip, flaring of the alar base, and opening of the nasolabial angle.[14] Several techniques have been proposed to help control unwanted soft tissue changes associated with maxillary surgery. Herford *et al*.[15] described a conservative maxillary vestibular incision for SARPE that preserved large portions of the upper lip mucosa and musculature. Nevertheless, the most commonly employed technique for controlling lateralization and thinning of the upper lip remains the V-Y closure. The standard V-Y closure is accomplished by anteriorly retracting and closing the midportion of the vestibular incision before bilaterally closing the remaining arms of the flap. This approach restores fullness to the upper lip, increases vermilion exposure, and enhances the curvature of Cupid's bow.[16,17] Originally described by Millard[18] for use in patients with cleft lip, alar base cinch sutures are another technique commonly employed to improve cosmesis following maxillary osteotomy. Alar cinch techniques attempt to reapproximate the fibroadipose tissue of the alar base and facilitate muscular reattachment at their original insertions. Alar cinches are frequently placed before vestibular closure to mitigate unfavorable increases in alar base width (ABW) following orthognatic surgery.

The advancements and availability of three-dimensional imaging technologies have augmented the body of literature concerning soft tissue changes accompanying palatal expansion. In LeFort I osteotomies, manipulation of both skeletal and soft tissues is believed to secondarily alter the nasolabial physiognomy and aesthetics of patients.[11] Quantifying the soft tissue ABW changes accompanying SARPE will aid in understanding these dynamic connections and be critical to the treatment planning process.

Because the power of past surgical studies is limited by their enrollments, this analysis attempts to strengthen or weaken the claims made in those studies by pooling effect sizes and testing the significance of the overall mean effect. The purpose of this article was to present the results from a meta-analysis that was conducted to investigate the stability of soft tissue alar base width changes associated with SARPE.

Materials and Methods

Objective

The primary objective of this study was to investigate soft tissue ABW changes a minimum of 6 months following SARPE.

Search strategy

The following electronic databases and citation indexes were searched: PubMed, Cochrane Library, Scopus, Web of Science, Embase, and Virtual Health Library. The search included articles published until September 2015 without language restriction. The general search term was palatal expansion OR maxillary expansion OR SARPE OR SARME) AND (alar base OR nasal width). In addition, references of eligible articles and gray literature conference proceedings were hand-searched by the investigators for relevant articles. Citations from each database were exported to EndNote® (Thomson Reuters; Carlsbad, CA, USA), a bibliographic management software.

Inclusion and exclusion criteria

The intervention was SARPE with maxillary vestibular incision from first molar to contralateral first molar, a modified LeFort I osteotomy with or without pterygomaxillary disjunction, and V-Y closure. The primary outcome was the unstandardized mean difference between pre and postoperative ABW.

Duplicate entries were discarded. Reviews, case studies, and commentaries were excluded from the results. The criteria for inclusion were as follows: (1) prospective and retrospective human clinical trials; (2) patients with no prior history of craniofacial surgery; (3) patients submitted to SARPE with a modified LeFort I osteotomy as described above; (4) ABW measured with soft tissue landmarks; (5) follow-up ABW data a minimum of 6 months postoperative; (6) no surgical complications. No restriction was placed on the origin of malocclusion. Articles from each database were screened for relevancy by titles and abstracts.

Data collection and assessment of risk of bias

Two investigators independently performed article searches, and reviewed titles and abstracts of their search results. Duplicate articles and those not meeting the eligibility criteria were removed. Full-texts of all potentially eligible studies were obtained and verified for eligibility. Following data abstraction, only eligible papers were included in the quantitative and qualitative analyses.

The risk of bias at the study level was assessed using the guidelines outlined in the Cochrane Risk of Bias Tool.[19] These guidelines recommend imposing quality criteria and judging each study as "low risk," "high risk," or "unclear risk" of bias. These criteria relate to the following risk of bias categories: Random sequence generation (selection bias), intention to treat (selection bias), blinding of participants and personnel (performance bias), incomplete outcome data (attrition bias), and selective reporting (reporting bias) [Figure 1].

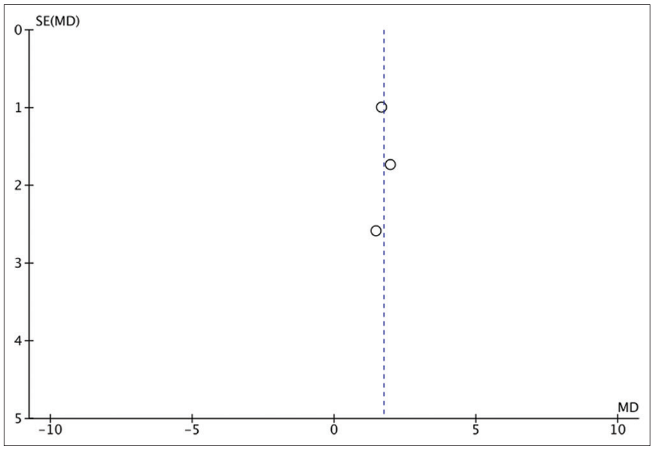

Figure 1: Funnel plot of standard error vs mean difference for assessing reporting bias; vertical line is the population effect size estimate

Data analysis

A meta-analysis was performed to combine studies results using the Review Manager software (Version 5.2, Copenhagen: Nordic Cochrane Centre, Cochrane Collaboration, 2015). The pooled estimate of effect size was calculated using the inverse variance weight model. In this model, the relative weight of each study was determined from the inverse of the variance of the effect estimate. The standard error (SE) of each study's effect size was calculated, and 95% confidence intervals (95% CI) were provided for each study's estimate. Although a previous meta-analysis on a similar topic[6] used a fixed-effect model, the authors of this study decided that a random-effect model was more appropriate because there does not exist a single true effect size among the patient-to-patient variability in amount of expansion. In addition, a random-effect model is statistically less powerful, and therefore, more conservative, and both random and fixed-effect models usually agree when there is no heterogeneity.

The included studies were assessed for statistical heterogeneity using a Chi-square test for independence. A P value < 0.10 from the Chi-square test was taken to indicate significant heterogeneity. An I^2 statistic was calculated from the χ^2 test statistic; 30% < I^2 < 50%; 50% < I^2 < 75%; and I^2 > 75% were defined to indicate moderate, substantial, and considerable heterogeneity, respectively.[20]

Results

Description of included studies

The searches revealed 348 results of which there were 123 unique titles and abstracts [Figure 2]. Duplicate publications (225) appearing in more than one database were considered only once. Ultimately, 7 studies were found to meet the inclusion criteria, of which 3 had data presented in a useable manner [Table 1]. Of note,

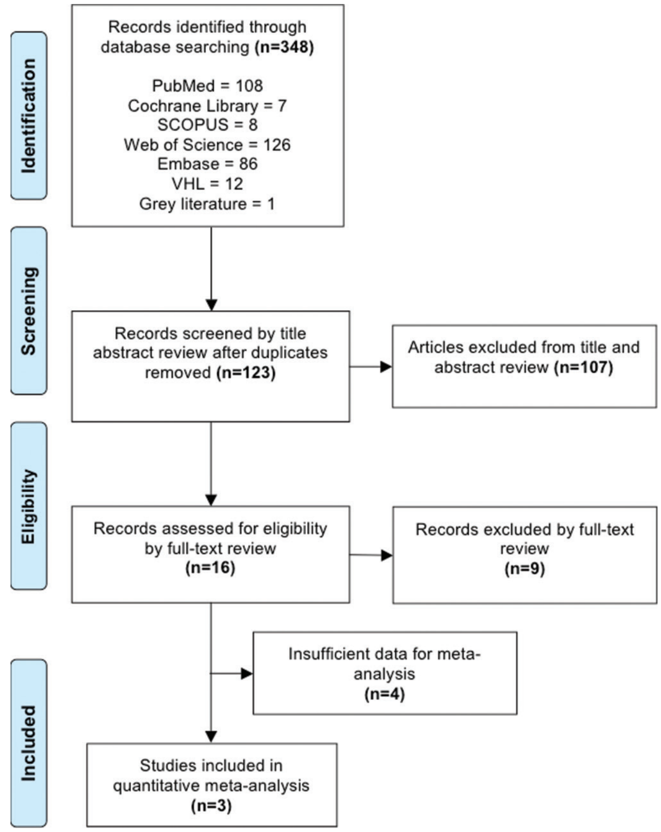

Figure 2: Flow chart describing systematic research search and study selection process

hand search of conference proceedings revealed 1 study[21] that was presented at the 2009 AAMOS 91st Annual Meeting (Toronto, ON). That study was included in this meta-analysis after the authors were contacted and were able to provide the necessary information for inclusion.

The authors identified 7 pertinent studies[9,21-26] investigating ABW changes following SARPE. Four of these studies[9,22-24] did not present ABW data in terms of individual time period means and distributions, and consequently were excluded from the analysis. The measurements of the remaining 3 included studies[21,25,26] were obtained from either three-dimensional landmarks or digital calipers. Diamantis *et al*.[21] captured three-dimensional images with stereophotogrammetry, and in that study inter-rater reliability was found to be within the control limits. Likewise, Metzler *et al*.[26] captured three-dimensional photogrammetric images and measured soft tissue landmarks after consensus by two independent observers. de Assis *et al*.[25] performed alar measurements with a digital caliper using the same research fellow to make all measurements. Diamantis *et al*.[21] simply defined the measurement limits as the lateral boundaries of the alar base. Metzler *et al*.[26] measured ABW from subalare, defined as the lowest point of alar base where the ala meets the nose. de Assis *et al*.[25] measured widths with a digital caliper laid

Table 1: Summary of studies meeting inclusion criteria

Author, year	Type of study	Location	Method	Age (y)	Sample (n)	Follow-up	Soft tissue landmark	Surgical procedure	Distraction modality	Mean ABW change (mm)	Adequate statistics for meta-analysis?
Berger *et al*., 1999	PS	USA	Frontal photograph	(mean=19.3)	24	12 mo after appliance removal	Distance between right and left ala	LeFort I osteotomy	TB expander Latency period: 2-3 mo Mean expansion of 5 mm Retention phase: 1y (transpalatal arch)	+2.10§	N; missing pre- and postoperative ABW SDs
de Assis *et al*., 2010	PS	Brazil	Digital caliper	18-28 (mean=26.5)	13	6 mo postoperative	Lateral face of alar insertions	LeFort I osteotomy Without pterygomaxillary disjunction Without nasal septum osteotomy All received alar cinch sutures	TB expander 1 mm initial activation Activation rate: 2x/day (total, 0.5 mm/day) Retention phase: 4 mo	+1.69§	Y
Diamantis *et al*., 2009	RS	USA	3D image	12-46	16	≥6 mo postoperative	Lateral boundaries of alar base	LeFort I osteotomy With pterygomaxillary disjunction Half (8) received alar cinch sutures	TB expander Activation rate: 2x/day (total, 1 mm/day) Expansion until "sufficient transverse width"	+1.49§	Y
Filho *et al*., 2002	PS	Brazil	Digital caliper	N/A	23	≥6 mo postoperative	N/A	LeFort I osteotomy With pterygomaxillary disjunction Osteotomy of median palatal raphe and maxillary alveolar process at the median line Half (11) received conventional simple closure Half (12) received VY-closure	TB expander	+4.21§ (conventional suture); +3.47§ (VY-closure)	N; missing pre- and postoperative ABW SDs
Magnusson *et al*., 2013	PS	Sweden	3D image	16.1-43.9 (mean=19.7)	35	18 mo postoperative	Most lateral points of the alar base	LeFort I osteotomy Without pterygomaxillary disjunction Vertical osteotomy at the anterior nasal spine and the median palatal suture	TB expander Latency period: 5d Activation rate: 2x/day (total, 0.45-0.50 mm/day) for a mean of 15d "Bilateral overexpansion of half a molar-cusp width." Retention phase: 90d	+3.09§ (median)	N; presented median and percentile, not means and SDs
Metzler *et al*., 2014	RS	USA	3D image	16-34 (mean=17.3)	12	≥6 mo postoperative	Subalare (= lowest point of alar base where the ala meets the nose)	LeFort I osteotomy With pterygomaxillary disjunction All received alar cinch sutures	TB expander Activation rate: 2x/day (total, 1 mm/day) Overexpansion of 3 mm Retention phase: ≥12w	+2§	Y

Contd...

Table 1: Contd...

Author, year	Type of study	Location	Method	Age (y)	Sample (n)	Follow-up	Soft tissue landmark	Surgical procedure	Distraction modality	Mean ABW change (mm)	Adequate statistics for meta-analysis?
Ramieri *et al.*, 2008	PS	Italy	3D image	18-35 (mean=24)	18	6 mo and 12 mo postoperative	Distance between right and left alar crests	LeFort I osteotomy With pterygomaxillary disjunction Midline buccal corticotomy	BB expander Latency period: 7d Activation rate: 0.33 mm/day (first 7d) 0.6 mm/day (until desired endpoint) Retention phase: 4-6 mo	+0.8 (6 mo); +1.4§ (1y)	N; only mean and SD of change score was presented

RS – Retrospective study; PS – Prospective study; ABW – Alar base width; N/A – Not available; TB – Tooth-borne; BB – Bone-borne; § – Statistically significant ($\alpha<0.05$)

between the alar insertions at a point that appeared to be chosen superior to the alar-facial grooves.

Risk of bias in included studies

The studies included in the meta-analysis did not overturn the null hypothesis of homogeneity ($\chi^2 = 0.03$; df = 2; $P = 0.98$). Thus, there was no significant evidence to suggest that the 3 combined studies[21,25,26] were not undertaken in the same manner and to the same experimental protocols. Nearly all the variability across the studies was a consequence of chance and not heterogeneity among studies ($I^2 = 0\%$).

Metzler *et al*.[26] conducted a retrospective analysis and included all patients who underwent SARPE from November 2012 to July 2013. The observers measuring the images were not blinded to the study. Diamantis *et al*.[21] conducted a retrospective analysis but did not specify their criteria for selecting patient records. In addition, in that same study, the decision to cinch some and not others was not elaborated, and the research fellows collecting the data were not blinded to the study. de Assis *et al*.[25] conducted a prospective longitudinal study but did not mention the sampling criteria. Patients who were lost to follow-up were not compared to patients who adhered, and it is unknown if attrition bias affected the results. In addition, the researchers measuring ABWs were not blinded to the study.

In summary, none of the studies blinded the researchers measuring the pre and postoperative ABWs. The two retrospective studies[21,26] likely analyzed convenience samples collected over a specified period. In one study,[25] the risk of incomplete outcome data lost to follow-up was not clear [Table 2].

Outcomes

ABW was compared across all studies. Studies where change scores were presented but where pre and postoperative data were not individually available were unable to be included.[9,22] In those instances, authors were solicited for pre and postoperative means and standard deviations.

The comparison of the ABW was obtained a minimum of 6 months postoperatively. Regions lateral to the nasal alar crests were used as homologous reference landmarks to assess ABWs. The soft tissue changes associated with SARPE were found to be statistically significant in the lateral dimensions of the ABW [Figure 3] (Pooled effect, +1.74 mm; 95% CI, 0.14–3.34; $P = 0.03$).

Discussion

The clinical significance of a systematic review

Qualitative systematic reviews have been published evaluating dental and skeletal changes accompanying

Table 2: Risk of Bias Summary

	Random sequence generation (Selection bias)	Intention to treat (Selection bias)	Blinding (Performance bias)	Incomplete outcome data (Attrition bias)	Selective Reporting (Reporting bias)
de Assis *et al*., 2010	?	+	-	-	+
Diamantis *et al*., 2009	+	-	-	+	?
Metzler *et al*., 2014	+	+	-	+	+

'+' – Low risk of bias; '–' – High risk of bias; '?' – Unclear risk of bias

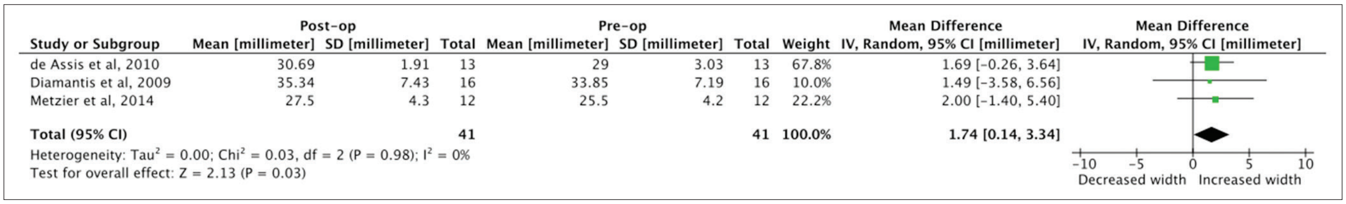

Figure 3: Follow-up outcome of alar base width in millimeters

SARPE.[27] In 2012, Vilani *et al*.[6] published a quantitative meta-analysis assessing the long-term changes to the alveolar maxillary, intercanine, and intermolar widths. It was found that those dimensions demonstrated significant increases as a result of SARPE.[6] Till date, neither a systemic review nor a meta-analysis has been published concerning the soft tissue changes accompanying SARPE.

A major objective of orthognathic surgery is the aesthetic outcome. Treatments only correcting for dentoskeletal deformities are not sufficient for optimal facial results because undesirable soft tissue changes may accompany skeletal manipulations. To achieve a favorable outcome, it is therefore important for clinicians and patients to consider both the surgical procedure and extent of expansion as contributing factors. In patients presenting with a class II malocclusion, vertical maxillary excess, or reduced ABW, postoperative nasal width increases may actually balance nasal-facial proportions and be considered beneficial.[28] In patients with normal or already enlarged ABWs, further increases may be viewed as undesirable and aesthetically unpleasing.[28-30] For a favorable outcome, the final ABW should ideally mirror the intercanthal distance in Caucasian patients.[31]

Main findings

Many studies have been published evaluating the skeletal and dental changes accompanying SARPE, but comparatively fewer studies have investigated the nasolabial soft tissue changes. The results from this meta-analysis showed a significant ABW increase of +1.74 mm in patients submitted to SARPE. The 4 studies[9,22-24] excluded from the analysis because of incompatible statistics demonstrated significant ABW widening a minimum of 6 months postoperatively as well.

Impact of cinch sutures on alar base width changes

In this meta-analysis, intraoral alar cinch sutures were placed in all 3 included studies.[21,25,26] However, none of the studies[16,20,21] elaborated their techniques or indications for cinching. de Assis *et al*.[25] and Metzler *et al*.[26] both cinched all patients. The criterion for selectively cinching some and not others was not explicitly outlined by Diamantis *et al*.[21]

The efficacy of alar cinch sutures remains embroiled in debate. As supported by the results of our meta-analysis, significant ABW increases were still observed despite the presence of alar cinch sutures. However, Stewart *et al*. found that these ABW increases were appreciably minimized when compared to noncinched controls.[28] Other studies[32,33] have found that a modified intraoral suture did not significantly alter the ABW. Betts *et al*.[34] found that alar cinch sutures actually widened the alar base following a LeFort I osteotomy for maxillary repositioning, an observation shared by Diamantis *et al*.[21] The efficacy of alar cinch sutures is likely a function of both (1) the cinching technique[35] and (2) the judgment of the surgeon at the time of suture placement.

Etiology and stability of soft tissue migration

Subperiosteal dissection and osseous base expansion are thought to be the primary mechanisms of nasolabial thinning and lateralization. However, the extent of soft tissue migration also depends heavily on a variety of other factors such as racial/ethnic variations of nasal dimensions and tissue elasticity. It must also be considered that some changes, such as upper lip positioning, stem from diastema closure and other Phase II orthodontics following palatal expansion.[22]

Recently, the concept of distraction histogenesis has found application in craniofacial biology.[36] The term distraction histogenesis more accurately describes the physiological changes associated with distraction osteogenesis because evidence suggests that orthopedic distraction expands and remodels not only the skeletal base but also the surrounding soft tissues.[36,37] Various tissues, including the skin, muscle, tendon, vasculature, and gingiva, respond via hyperplasia to augment and gradually adapt to the bony changes. Therefore, the long-term benefits of alar cinch sutures and V-Y closure might not be from functional reapproximation of muscular insertions or the introduction of midline tension. Rather, those techniques may simply act to splint the surrounding tissues and structures and allow sufficient time for soft tissue remodeling to occur. Likewise, gradual tissue remodeling could explain the tendency of facial measurements to fluctuate throughout and beyond the retention phase of SARPE.[9,22]

Quality of evidence

Meta-analysis is a statistical technique for combining findings from independent studies, and therefore, any analysis is only as reliable as the studies that comprise it.[38] None of the 3 included studies[21,25,26] was completely free of bias. The most prominent flaws were performance bias, sample size, and patient recruitment. All 3 studies[21,25,26] failed to blind outcome assessors, and because the measurement of the ABW is partially up to individual judgment, the measurements could have been affected. These drawbacks might influence the validity of the findings of this meta-analysis.

Limitations

This analysis provides evidence that patients submitted to SARPE will experience stable postoperative increases in soft tissue ABW. Furthermore, the presence of intraoral alar cinch sutures did not completely negate these increases. The applicability of this evidence is limited by a few considerations.

A primary limitation of this study was the various methods each author used to assess ABW. The ABW is defined as the lateral distance between the inferior most insertions of the alar-facial grooves. It was noted that many authors researching this same outcome often mistook the alar width as the ABW.[32,33,39] As long as the method was consistent within a given study, the reported measurements were eligible for inclusion in this meta-analysis because the primary outcome was calculated as a change score.

Another limitation of this meta-analysis was the incongruity of postoperative follow-up times. In all studies, patients underwent orthodontic treatment following a postoperative latency period. The magnitude of orthodontic expansion achieved at the time of follow-up measurement likely influenced the degree of soft tissue change. Cinching protocols and surgeon variability possibly influenced the results as well. However, the low heterogeneity among studies suggests that these and other differences in study design were not significant to the results. Finally, the quantitative evidence was derived from adults in the USA and in Brazil. Caution should be taken when applying these results to other ethnic groups and to children, as there are natural variations in nasal and facial dimensions.

Future directions

Future research is expected to employ three-dimensional imaging for producing novel studies that utilize and track facial landmarks. Perspective distortion can occur during photography,[40] resulting in landmarks that are not in the same plane of space. Likewise, traced cephalograms for the purpose of measuring soft tissue landmarks have also been shown to be unreliable and inaccurate in controlled studies.[41] With the recent availability of affordable three-dimensional imaging technologies, interest in conducting soft tissue studies has increased. The reduced observational error coupled with the ability to quantify three-dimensional changes gives this technology an advantage over past two-dimensional data collection methods.

Standardization among experimental methods, availability of means and distributions (not just change scores) of all groups at all time periods, and three-dimensional measurement methods are important for homogenous comparisons in future soft tissue meta-analyses. Investigators should seek to correlate the magnitude of expansion with the magnitude of nasolabial changes to better manage soft tissue changes. Careful preoperative clinical examinations of the nasolabial structures may shed light as to whether these changes would enhance or detract from the final aesthetic outcome.

Conclusions

Following a meta-analysis, a statistically significant increase (+1.74 mm, 95% CI [0.14, 3.34]) in mean alar base width was observed a minimum of 6 months postoperatively in patients submitted to SARPE. Alar base width increases were observed despite including cinched patients in the analysis. The literature suggests that cinching reduces postoperative increases more often than it exacerbates them, and intraoral alar cinch sutures should be considered whenever an undesirable increase in alar base width is anticipated.

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Conflicts of interest

There are no conflicts of interest.

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