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Transpalatal vs anterior approach for pterygomaxillary disjunction in the context of surgically assisted MARPE: CBCT assessment

A. Lázaro-Abdulkarim [a,*], A. Valls-Ontañón [a,b], A. Puigdollers-Pérez [c], N. Clusellas-Barrionuevo [c], M. Giralt-Hernando [a], F. Hernández-Alfaro [a,b]

[a] Department of Oral and Maxillofacial Surgery, Universitat Internacional de Catalunya, Sant Cugat del Vallès, Barcelona, Spain
[b] Institute of Maxillofacial Surgery, Teknon Medical Center Barcelona, Barcelona, Spain
[c] Department of Orthodontics and Dentofacial Orthopedics, Universitat Internacional de Catalunya, Sant Cugat del Vallès, Barcelona, Spain

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ABSTRACT

This study aimed to evaluate the effects on skeletal, dentoalveolar, and craniomaxillofacial sutures, and on upper airway changes, of performing minimally invasive surgically assisted rapid palatal expansion (SARPE) with pterygomaxillary disjunction through an anterior approach, or using a combination of anterior and transpalatal pterygomaxillary osteotomy (TPMO) in maxillary expansion procedures. Pre- and postoperative cone-beam computed tomography (CBCT) images were obtained for each patient. Fifty patients were included: 25 in the control group (minimally invasive twist technique) and 25 in the test group (minimally invasive twist technique combined with TPMO). Both groups showed statistically significant maxillary expansion, with the test group exhibiting a greater anterior maxillary increase (5.60 mm versus 4.10 mm). Both groups experienced an increase in nasal cavity width, upper airway area, and pterygomaxillary disjunction. Buccal tooth inclination and increased palatal bone thickness were present in both groups. The frontonasal suture and zygomatic bone width remained equally stable. The results of study indicate that pterygomaxillary disjunction guarantees posterior palatal expansion, whilst other craniomaxillofacial sutures are not affected. However, transpalatal pterygomaxillary osteotomy allows a more precise split of the pterygoid suture, facilitates down-fracture of the maxilla, and ultimately decreases associated morbidity.

1. Introduction

Transverse maxillary deficiency is a relatively common type of malocclusion. Rapid palatal expansion (RPE) has been widely used to increase the transverse dimensions of the maxilla in growing patients (Brunetto et al., 2017; Storto et al., 2019) through using tooth-borne devices (Garib et al., 2005). However, separation of the midpalatal suture becomes gradually more difficult with age (Shin et al., 2019). Therefore, in adult patients where calcification and interdigitation of the craniofacial sutures have already occurred, RPE proves ineffective, and undesired dental effects — such as buccal tipping of the posterior teeth, decreased buccal bone thickness, and buccal root resorption — may result when tooth-borne devices are used (Moon et al., 2015; Suzuki et al., 2016; Park et al., 2017; Seong et al., 2018; Celenk-Koca et al., 2018; Shin et al., 2019).

In order to avoid these adverse effects, bone-anchored devices have been described in the context of miniscrew-assisted rapid palatal expansion (MARPE) (Lee et al., 2010), as well as extensive surgical procedures involving weakening of the resistant pillars through osteotomies (Storto et al., 2019; Haas Júnior et al., 2024). This well-established surgical strategy, known as surgically assisted rapid palatal expansion (SARPE), was first described by Brown in 1938 (Brown, 1938), and was classically linked with increased patient morbidity, the need for general anesthesia, and an inherent need for hospital admission (Choi et al., 2016; Brunetto et al., 2017; Park et al., 2017). Minimally invasive SARPE, described by Hernández-Alfaro et al. (2010), was conceived to reduce surgical morbidity. It is usually carried out under sedation, on an outpatient basis, while adopting a minimally invasive approach with full release of the maxillary resistances, implying low patient morbidity (Hernández-Alfaro et al., 2010).

Different areas of resistance to maxillary expansion have been described in the context of SARPE, and several modifications have been proposed as to where osteotomies should be performed. Separation of the pterygomaxillary junction is controversial in terms of the

* Corresponding author.
E-mail address: a.lazaro@uic.es (A. Lázaro-Abdulkarim).

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questionable benefits of releasing the pterygoid plates, and the possible complications resulting from damage to important anatomical structures, such as the descending palatine artery or the sphenopalatine fossa, as well as untoward fractures in adjacent bones (Koutsdaal et al., 2005; Hamedi-Sangsari et al., 2016). Although current discussions focus on whether pterygomaxillary disjunction (PMD) is really necessary to obtain a parallel expansion pattern, several authors have demonstrated that uniform and parallel maxillary expansion is more likely to be achieved when SARPE is combined with PMD (Zandi et al., 2016; Möhlhenrich et al., 2016; Ferraro-Bezerra et al., 2018; Möhlhenrich et al., 2021).

Traditionally, PMD was performed primarily using the curved chisel technique, but in order to avoid the potential complications linked with this technique and allow a minimally invasive approach, the anterior twist technique was introduced by Hernández-Alfaro and Guijarro-Martínez (2013). A few years later, the same group described a novel technique to ease maxillary down-fracture and reduce the risk of pterygoid plexus injury by means of a transpalatal pterygomaxillary osteotomy (TPMO) (Hernández-Alfaro et al., 2023).

Our study was carried out to investigate the benefits of transpalatal pterygomaxillary osteotomy before PMD through an anterior approach, and in the context of minimally invasive surgically assisted rapid palatal expansion. Accordingly, the effects on skeletal, dentoalveolar, and craniomaxillofacial sutures, and on the airway, were compared between patients undergoing minimally invasive SARPE with PMD through an anterior approach versus those with prior TPMO.

2. Materials and methods

2.1. Study design and sample selection

This retrospective cohort study involved consecutive patients undergoing maxillary osteotomy performed by two surgeons (FHA and AVO), conducted at the Institute of Maxillofacial Surgery (Teknon Medical Center, Barcelona, Spain).

The study included skeletally mature patients with a transverse maxillary deficiency, who required surgery to correct their dentofacial deformity between October 2013 and October 2023. Two cohorts were defined according to whether or not TPMO was performed before PMD: SARPE with anterior disjunction (control group) and SARPE with transpalatal pterygomaxillary osteotomy and anterior disjunction (test group). Since this novel TPMO technique was first described in 2022, all patients operated on before 2022 were included in the control group, while those operated on after January 2022 were included in the test group.

The patients were selected according to the following inclusion criteria: patients with transverse maxillary deficiency >5 mm and in need of maxillary correction involving SARPE; and the obtainment of written informed consent. Patients with combined bilateral sagittal split osteotomy were excluded, as were those with any craniofacial syndrome.

All patients provided written informed consent for the use of their cone-beam computed tomography (CBCT) scans, and the study was approved by the ethics committee of Teknon Medical Center (ref. 2024/38-MAX-CMT).

2.2. Surgical technique

Patients received either a tooth-borne (hyrax type) or maxillary skeletal expander (MSE), which was fitted by the orthodontist 5–14 days prior to surgery. The MSE consisted of a pure bone-borne device, with bicortical engagement using two or four miniscrews in the cortical bone of the palate and the nasal floor. Since it was a prerequisite that the miniscrews provided bicortical anchorage, and the expander had to be placed between the two halves of the palate, the expander was designed digitally using CAD software (Exocad GmbH, Darmstadt, Germany) from the superimposition of the CBCT and intraoral digital scans of the patient. The surgical procedures were conducted under local anesthesia and sedation by two maxillofacial surgeons (FHA and AVO). The control group consisted of patients treated prior to introduction of the new technique. This group was subjected to the standard minimally invasive twist technique described elsewhere (Hernández-Alfaro and Guijarro-Martínez, 2013), undergoing vertical and lateral osteotomies and subsequent PMD through a reduced anterior approach.

The control group data were collected retrospectively, and the patients were operated on between October 2013 and December 2020. The test group in turn underwent the same Le Fort I osteotomy surgery as the control group, but with the addition of TPMO, which was performed transpalatally using a piezoelectric hand-piece device (Piezomed, W&H, Bürmoos, Austria) (Hernández-Alfaro et al., 2023) (Fig. 1). The test group data were collected prospectively, and the patients were operated upon between January 2021 and October 2023.

In both groups, after the activation period, and once the desired expansion was achieved, the distractor was kept in place for at least 6 months for osseous consolidation.

2.3. CBCT image analysis

A cone-beam computed tomography (CBCT) (i-Cat; Imaging Sciences International, Hatfield, PA, USA) scan was taken prior to surgery (T0) and once expansion was completed (T1). In order to make the required 2D measurements, the CBCT models from the two intervals were superimposed using a commercial software program (Dolphin 3D Surgery, version 11.95; Dolphin Imaging and Management Solutions, Chatsworth, CA, USA) with a voxel-based protocol consisting of three successive ‘side-by-side superimposition’ steps.

Linear skeletal and dentoalveolar and volumetric upper airway measurements were taken in three different sections at T0 and T1. On evaluating the skeletal measurements, two coronal scans were obtained, passing through the central groove of the first premolars and molars. The following parameters were measured, taking as reference the most lateral point of each structure: maxillary width (MW), cementoenamel junction (CEJ), nasal cavity width (NCW), zygomatic width (ZW), orbital width (OW), and frontonasal width (FNW) (Fig. 2).

Also, in the coronal plane, the frontozygomatic suture width (FZS), zygomatic-temporal suture width (ZTS), and zygomatic-maxillary suture width (ZMS) were measured, taking the most lateral point of each structure as a reference (Fig. 3).

The width of the frontonasal suture (FNS) was measured as the distance between the edges of the fontal and the nasal bones in the sagittal plane (Fig. 4).

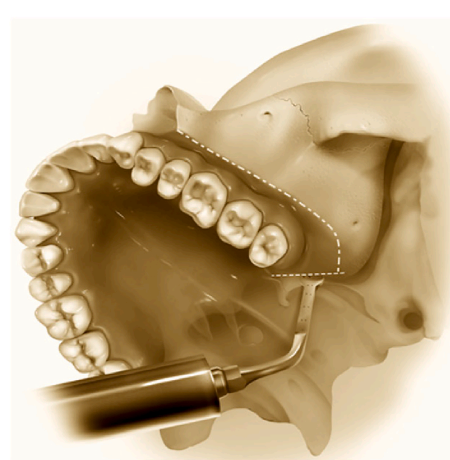

Fig. 1. Schematic representation of the transpalatal pterygomaxillary disjunction osteotomy and regional anatomy.

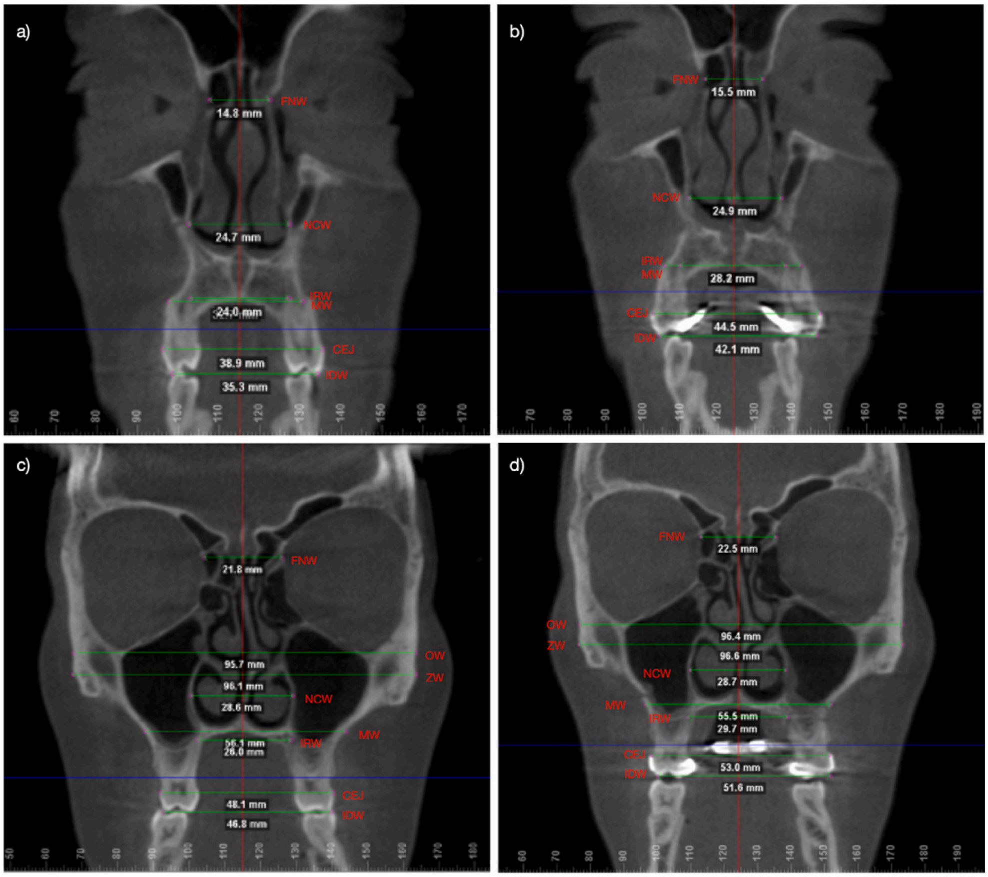

Fig. 2. Skeletal and dental measurements at the coronal section: (a) 1st premolar level at T0; (b) 1st premolar level at T1; (c) 1st molar level at T0; (d) 1st molar level at T1.

In the transversal plane, the opening of the midpalatal suture was measured as the distance between the mesial edges of the intermaxillary suture, at the level of the anterior (ANS) and posterior nasal spine (PNS) (Fig. 5).

Likewise, the opening of the pterygopalatine junction (thickness, TPMJ; and width, WPMJ) was evaluated on a transversal plane parallel with the palatal plane (Fig. 6).

On assessing the dentoalveolar measurements, the interdental cusp width (IDW) and interradicular width (IRW) were evaluated in the coronal plane at the level of the first premolar and molar (Fig. 1). In the transversal plane, the buccal/palatal bone width was measured by locating the external surface of the cortical plane and the surface of the buccal/palatal root at the level of the first premolar and molar (Fig. 7).

With regard to the upper airway dimensions, three regions of interest (ROIs) were evaluated in the sagittal plane: the nasopharynx (NP), delimited by the Frankfort horizontal (FH)–PNS–sphenoid bone and extended to the soft-tissue pharyngeal wall contour; the oropharynx (OP), delimited beyond the FH/PNS and extended to FH–most anterior point of the body of C3–soft-tissue pharyngeal wall contour; and the hypopharynx (HP), assessed as FH/PNS parallel–most anterior point of the body of C3–soft-tissue pharyngeal wall contour to FH/PNS parallel–most anterior pole of the body of C4 (Fig. 8).

2.4. Statistical analysis

Two examiners (ALA and AVO) performed all measurements. To determine intra- and interexaminer reliability, the examiners reanalyzed 25 % of randomly selected parameters after a 2-week interval. The kappa statistic (κ) was used to evaluate the level of agreement between examiners. In each patient, images from the identical axial, sagittal, and coronal planes from each CBCT scan were selected by the examiners. The data were entered in a database that was subsequently validated for analysis. The analyses were carried out using the SPSS version 15.0.1 statistical package for MS Windows (SPSS Inc., Chicago, IL, USA). A general descriptive analysis of the categorical variables was made, reporting the values as absolute and relative frequencies, while continuous variables were reported as the mean, standard deviation (SD), range, and median. In turn, 95 % confidence intervals (95 % CIs) were generated using non-parametric tests.

The inferential analysis included the Brunner-Langer model for longitudinal data, to compare the changes in each parameter throughout follow-up, and Spearman's non-linear correlation coefficient to estimate the degree of association between continuous variables. To evaluate homogeneity between groups, Mann-Whitney U-tests, chi-squared independence tests, and Fisher's exact tests were used. The level of significance used in the analysis was 5 % ($\alpha = 0.05$).

3. Results

In total, 50 patients undergoing a minimally invasive SARPE technique were included in the study: 25 in the control group and 25 in the test group. There were 23 males (46 %) and 27 females (54 %), with a mean age of 34.7 ± 10.2 years (range 12–57). Seventeen patients (six males and 11 females) in the test group used an MSE expander (SAMARPE) and eight used hyrax expanders (SARPE); all patients (13 males and 12 females) in the control group used hyrax expanders (SARPE). The sample characteristics and patient distribution are shown in Table 1.

Linear transverse dimensions of the maxilla increased systematically in both groups. In the anterior maxilla, a mean increase of 4.10 mm was

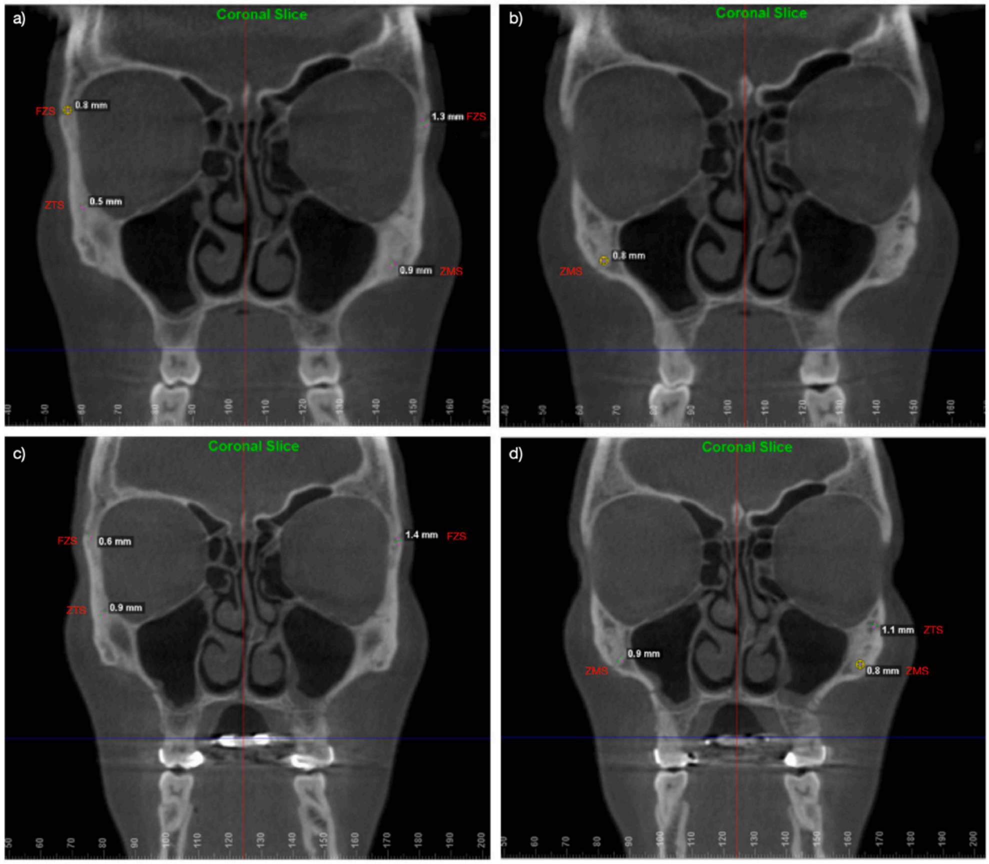

Fig. 3. Skeletal measurements in the coronal plane: (a) and (b) at T0; (c) and d) at T1.

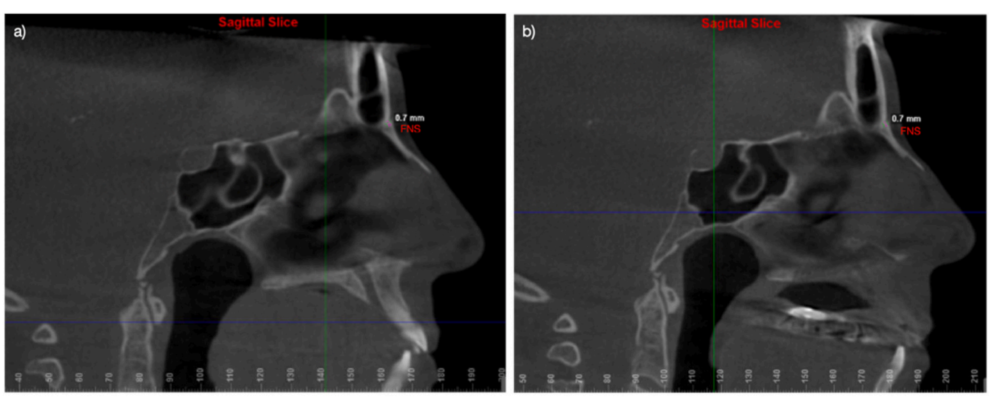

Fig. 4. Skeletal measurements at the level of the frontonasal suture in the sagittal section at (a) T0 and (b) T1.

observed in the control group, compared with 5.60 mm in the test group; the difference was statistically significant in favor of the test group ($p =$ 0.039). There was also an increase in the posterior maxilla in both groups ($p < 0.001$). With regard to the width at the level of the anterior nasal spine, there was a strong tendency ($p = 0.057$) towards a greater increase in the test group (6.7 mm) compared with the control group (6.0 mm). In contrast, there were no differences in the posterior nasal spine between the groups ($p = 0.531$). Across all cases, expansion was greater anteriorly than posteriorly, showing V-shaped expansion in the transversal plane. Moreover, the pattern of expansion was centered in 84 % of the cases in the control group, versus in 72 % of the cases in the test group. This difference was not statistically significant ($p = 0.243$).

The nasal cavity width increased after the procedure in a similar manner between groups, and this increase was more pronounced coronally than apically, showing a V-shaped expansion pattern also in the coronal plane.

Regarding the level of pterygomaxillary disarticulation, the results showed that both techniques offered the same efficacy, although the thickness of the junction increased significantly on the left side ($p <$ 0.003) and only showed a tendency to increased thickness on the right side ($p = 0.062$).

The radiographic analysis showed the frontonasal width to be stable in both groups ($p = 0.361$). Likewise, no changes were observed on evaluating the zygomaticomaxillary suture width. Thus, no fractures were observed at the cranial base after the surgically assisted expansion.

Regarding the upper airway, the nasopharynx surface increased significantly ($p = 0.005$) and equally in both groups ($p = 0.130$), while the oropharynx decreased significantly in the control group ($p = 0.041$).

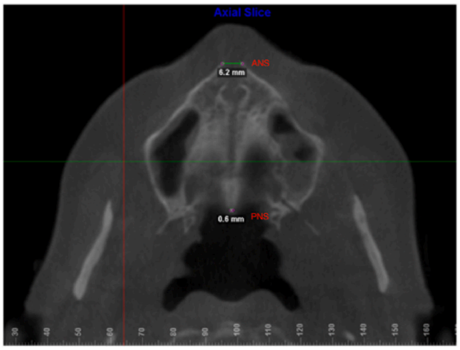

Fig. 5. Midpalatal suture width at the level of the ANS and PNS at T1.

Regarding the upper airway volume, this remained stable both at the naso- and oropharynx level ($p = 0.658$ and $p = 0.869$, respectively).

Tooth inclination to the buccal aspect was detected at the level of the first premolars and first molars, with statistically significant changes in both groups, but no differences between them. The alveolar process tipped buccally, and the palatal alveolar bone thickness increased significantly ($p < 0.001$) in all cases in both groups ($p = 0.578$ and $p = 0.587$, respectively).

The intraexaminer ICC obtained for measurement changes was 0.82–0.85 for both examiners; the interexaminer ICC was 0.78.

4. Discussion

Having described the osteotomy of the pterygomaxillary suture through the palatal mucosa, the authors aimed to assess the benefits of this maneuver just prior to conventional SARPE, through a minimally invasive approach with anterior PMD. Although this additional osteotomy eases down-fracture of the pterygomaxillary suture, as described elsewhere (Hernández-Alfaro et al., 2023), no differences have been demonstrated regarding the pattern of expansion and airway gain, or dentoalveolar and craniomaxillofacial suture side effects. Therefore, it

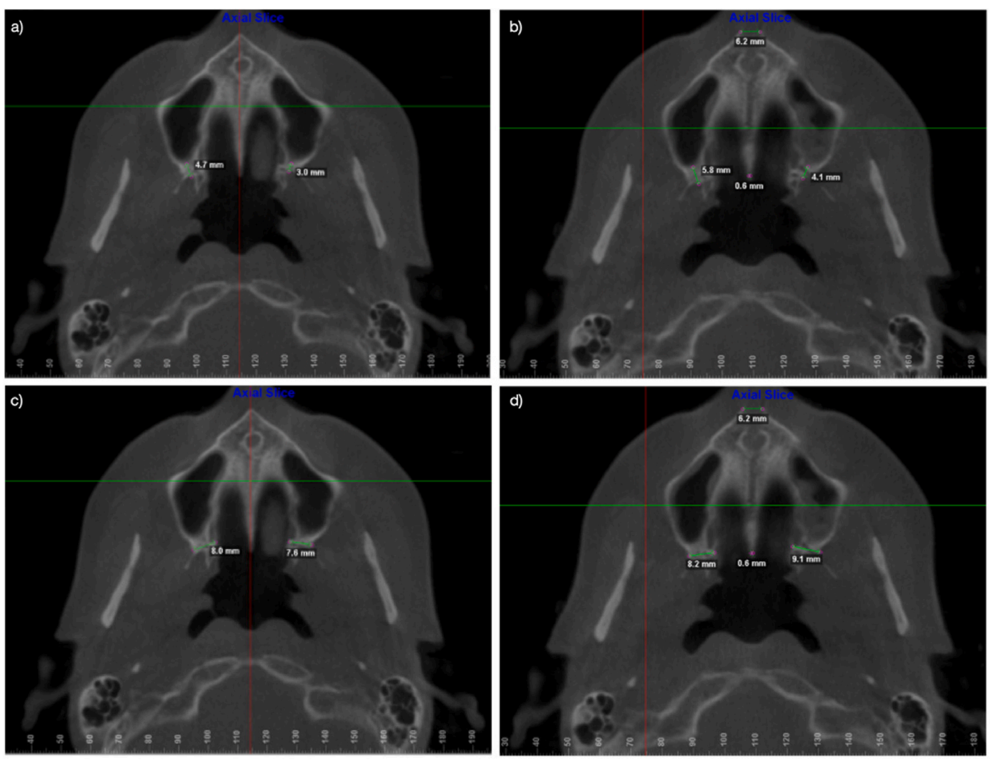

Fig. 6. (a and b) Thickness of the pterygomaxillary junction at T0 and T1, respectively. (c and d) Width of the pterygomaxillary junction at T0 and T1, respectively.

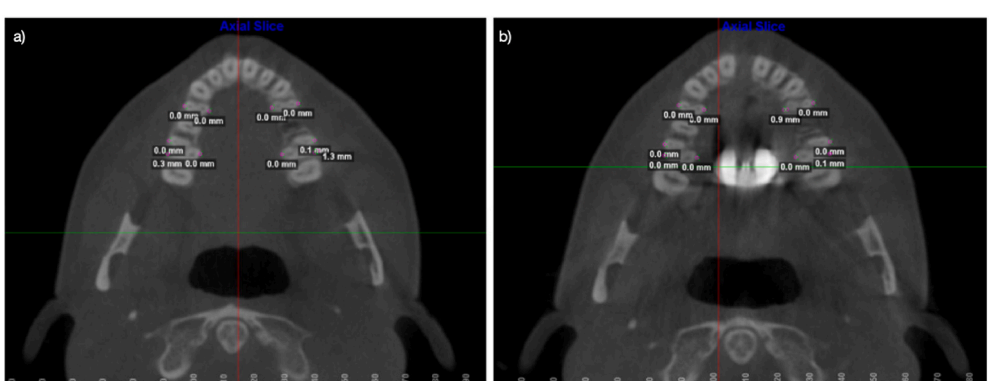

Fig. 7. Dentoalveolar measurements at the transversal section at (a) T0 and (b) T1.

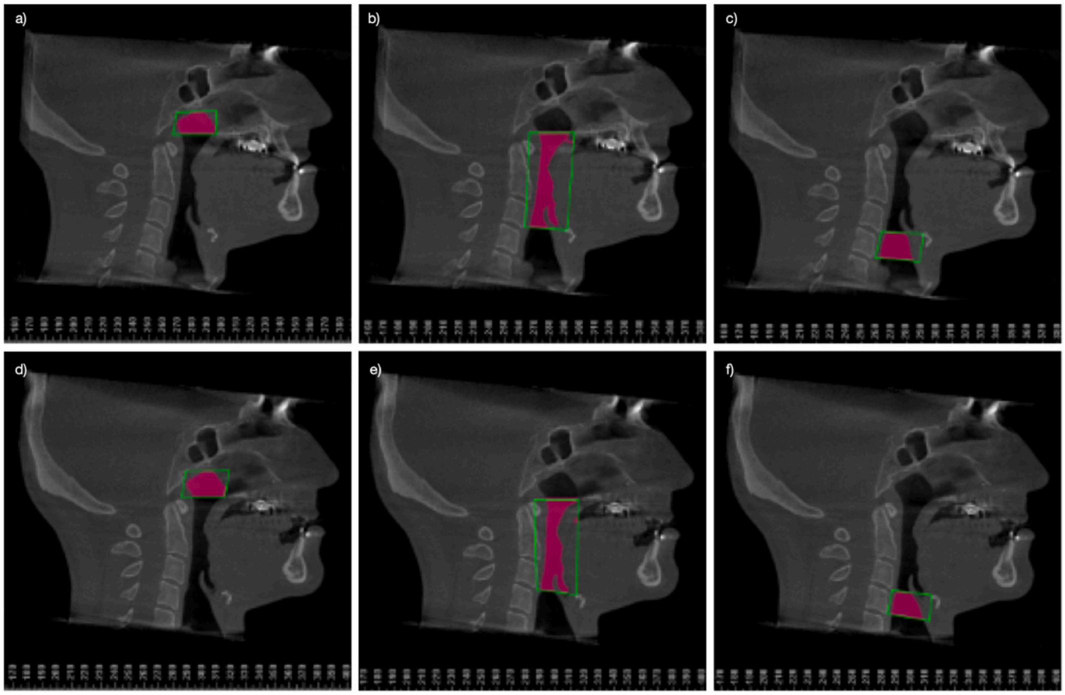

Fig. 8. Upper airway measurements: (a–c) naso-, oro-, and hypopharynx volume measurements at T0, respectively; (d–f) naso, oro-, and hypopharynx measurements at T1, respectively.

Table 1
Sample characteristics and patient distribution.

Group	Skeletal anchorage, SAMARPE (*n*)	Hyrax anchorage, SARPE (*n*)	Total, *n* (%)
Control	0	25	25 (50 %)
Test	17	8	25 (50 %)
Total sample	17	32	50
Mean age			34.7 ± 10.2
Sex			23 male, 27 female

can be confirmed that the evaluated variables are more related to the fact that PMD is carried out than to the way in which it is carried out.

Traditionally, detaching the pterygoid plates with osteotomes has been described as the most painful and inconvenient phase of the surgical procedure (Kilic et al., 2013). Nowadays, transmucosal pterygomaxillary osteotomy facilitates the maxillary down-fracture procedure, allowing definitive separation of the pterygomaxillary suture, as it decreases the resistance when performing the down-fracture maneuver and allows a clean and controlled fracture just at the junction, thus avoiding undesired deviations to the tuberosity or the pterygoid bone (Hernández-Alfaro et al., 2023).

At the pterygoid level, the linear transverse dimensions increased significantly after SARPE in both study groups. These findings were consistent with those of other studies (Camps-Perepérez et al., 2023). This could be explained by the fact that pterygomaxillary suture disjunction was performed in all cases, with down-fracture of the maxilla, but the TPMO performed in the test group reduced the resistance and increased the precision of the fracture on performing the twist maneuver for maxillary down-fracture, thus facilitating complete release of the anterior, lateral, posterior, and medial buttresses. These data are in line with the study published by Verplanken et al. (2024), in which finite element analysis (FEA) showed that performing pterygomaxillary disjunction reduced posterior resistance to transverse expansion, resulting in a 10–20 % reduction of stress around the maxillofacial complex. This was further confirmed by different clinical studies, concluding that even though pterygoid detachment does not fully eliminate all posterior bone resistance to the point of modifying the pattern of expansion (Magnusson et al., 2009), it does seem to facilitate better transverse bone movement (Ferraro-Bezerra et al., 2018).

In contrast, and with the aim of reducing perioperative complications, some authors have recommended performing SARPE without pterygomaxillary disjunction, because no differences in the amount and pattern of expansion were observed (Zandi et al., 2016). These results should be interpreted with caution, however, since the surgical techniques used in earlier studies were based on extensive procedures associated with potential morbidities, whereas the minimal approach used nowadays has drastically reduced the number of complications associated with this type of surgery.

The areas of resistance to maxillary expansion have been classified as follows: anteriorly, the piriform aperture pillars; laterally, the zygomatic buttresses; posteriorly, the pterygomaxillary junction; and medially, the midpalatal synostosis suture (Kilic et al., 2013; Cakarer et al., 2017). It seems clear that the minimally invasive SARPE procedure is the ideal option for maxillary expansion in mature patients; however, there are no predictable guidelines as to whether PMD is necessary or not.

As an outcome of our study, following the minimally invasive SARPE technique, a significant increase in the anterior and posterior skeletal transverse measurements was observed in both groups, without compromising the craniomaxillofacial sutures. However, the anterior region of the maxilla showed a greater increase in the test group, probably because the vast majority of expanders used in this group were purely bone-borne expanders. The anterior region also experienced a greater increase than the posterior region in the transversal measurements in both groups, as well as higher expansion in the coronal region compared with the apical region in the coronal plane. These V-shaped opening patterns in both the coronal and the transversal planes are more relevant when separation of the pterygoid plates is not carried out (Ferraro-Bezerra et al., 2018; Camps-Perepérez et al., 2023; Haas Júnior et al., 2024; Bastos et al., 2024).

The reported slight V-shaped pattern was in concordance with the literature, since the influence of the location of the expander and both bone and muscle forces persisted (Möhlhenrich et al., 2021). The authors could not compare the results versus a group without PMD, since the procedure has always been performed in the context of minimally invasive SARPE. If there had been a group without PMD, it would probably have resulted in a more pronounced triangular opening pattern, as reported in the literature (Ferraro-Bezerra et al., 2018; Möhlhenrich et al., 2021) — although some authors have reported parallel patterns without PMD (Zandi et al., 2016; Moura et al., 2016).

The wide range of patterns of expansion after SARPE could be related to multiple factors, such as patient sex, age, different surgical techniques, expander type and its anatomical position, and patient anatomy. With regard to the age of the sample, although SARPE is normally performed in skeletally mature patients, a 12-year-old patient was included in this study due to expansion failure using a nonsurgical approach. In relation to the effects of the type of expander (Asscherickx et al., 2016), the initial cases were treated with tooth-borne expanders, involving the entire control group and less than a third of the patients in the test group — a factor that could have introduced some bias. Moreover, the impact of expander location has been recently assessed in an ex-vivo and finite element analysis (FEA), concluding that a more posterior placement of the bone-borne expander facilitates more parallel expansion (Möhlhenrich et al., 2021; Verplanken et al., 2024).

Another important finding from our study was the increased nasal cavity width after SARPE in both groups. Zandi et al. (2014) also reported a slight increase in nasal width using tooth-borne expanders, although statistical significance was not reached. Other studies (Salgueiro et al., 2015; Romano et al., 2022) have reported similar results, although there was a tendency towards relapse after the stabilization period. According to several studies (Wriedt et al., 2001; Nada et al., 2013), increasing the cross-sectional area of the nasal cavity might facilitate easy breathing, although additional studies are needed to confirm these effects on respiratory function. Thus, SARPE, as an isolated procedure, cannot yet be recommended for improving nasal airflow.

Considering the influence of PMD on the upper airway volume changes, Medeiros et al. (2017) reported that PMD resulted in a significant increase in nasopharynx volume after active expansion and after 6 months of follow-up. In addition, a recent systematic review reported a significantly increased oropharynx area and volume at the level of the nasopharynx and the oropharynx when SARPE was associated with pterygomaxillary disjunction (Barone et al., 2024). Dissimilar results were obtained in our study. Even though the nasopharynx area increased significantly after minimally invasive SARPE, independently of whether pterygomaxillary disjunction was performed or not, the nasopharynx and oropharynx volume remained stable throughout the evaluation period. Overall, and despite the upper airway changes reported in the literature, there is no consensus on the correlation between PMD and increased airflow during breathing in treating apnea problems, considering this procedure a correction of orthognathic problems rather than respiratory dysfunction.

An aspect of concern that is not always taken into account, is the effect of maxillary expansion on speech articulation. Some authors have found significant phonetic changes due to RPE (Macari et al., 2016; Biondi et al., 2017). In addition, a recent systematic review suggested that RPE causes temporary changes in speech articulation during and after treatment, probably due to appliance use, returning to normal parameters a few months after the end of the treatment (Sant'Anna et al., 2024). Clinicians should alert patients about this effect, and provide relevant guidelines to patients and their families.

On the other hand, our study found no displacement of other craniomaxillofacial sutures. This opening pattern has also been reported by other investigators, such as Ferraro-Bezerra et al. (2018) and Romano et al. (2022), who reported a stable zygomatic maxillary pillar without skeletal changes in the zygomatic arch when surgery was carried out. Moreover, on assessing stress distribution in the maxillofacial complex in an FEA, Verplanken et al. (2024) found the zygomatic arch and the frontonasal sutures to be the least stressed structures. This was in agreement with the results obtained in our study, and is probably associated with the fact that the osteotomies were located inferior to the zygomatic bone; therefore, no changes should be observed above that level. In contrast, when palatal expansion is carried out without surgery in adult patients, the above craniofacial sutures suffer some degree of stress (Cantarella et al., 2018; Lee et al., 2021).

One of the most undesirable effects after SARPE is the existence of dentoalveolar changes. In our study, the anchor teeth suffered buccal tipping in both groups; consequently, buccal cortical plate thickness decreased, while palatal plate thickness increased. These findings were consistent with those of other studies (Ferraro-Bezerra et al., 2018; Camps-Perepérez et al., 2023). An explanation for these results could be related to the fact that almost 65 % of the expanders used in this study were tooth-borne devices. In order to overcome the periodontal side-effects, MSE replaced tooth-borne expanders, but their introduction took place in the last 2 years of the 10 years of the study.

There were some limitations to our study relating to its retrospective/prospective design, which, combined with the relatively small sample size, could affect the results obtained. In addition, the heterogeneity of the types of expander and their positions could have played a role in achieving more anterior or posterior expansions. On the other hand, adding a group without PMD could have introduced relevant data. Randomized clinical trials are thus necessary to advance the study of this issue.

5. Conclusions

Significant changes in all maxillary width parameters were seen in the total patient population after surgically assisted maxillary expansion with pterygomaxillary disjunction, despite the performance of transmucosal osteotomy. Our results thus indicated that PMD guarantees posterior palatal expansion, while other craniomaxillofacial sutures are not affected. However, transmucosal pterygomaxillary osteotomy allows a more precise split of the pterygoid suture, facilitates downfracture of the maxilla, and ultimately reduces associated patient morbidity.

CRediT authorship contribution statement

Aida Lázaro-Abdulkarim: conceptualization, methodology, validation, investigation, data curation, writing — original draft preparation, supervision. Adaia Valls-Ontañón: conceptualization, methodology, validation, investigation, writing — reviewing and editing, supervision. Andreu Puigdollers-Pérez: conceptualization, supervision. Núria Clusellas-Barrionuevo: conceptualization, supervision. Maria Giralt-Hernando: formal analysis, validation, supervision. Federico Hernández-Alfaro: conceptualization, supervision.

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Declaration of competing interest

The authors declare that they have no conflicts of interest.

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