

Velopharyngeal Space Assessment in Patients Undergoing Le Fort 1 Maxillary Advancement

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Background: The effects of maxillary advancement on velopharyngeal anatomy have primarily been studied using lateral cephalometric radiographs. However, with recent advances in orthognathic surgery, there is an increased need for more detailed and precise imaging such as computerized tomographic (CT) scan reconstructions, to help in surgical planning and to measure outcomes. The purpose of this study was to compare the pre- and post-operative velopharyngeal anatomic configuration modifications as measured on CT scans.

Methods: This is a retrospective cohort study of 44 patients with and without cleft palate who were treated with maxillary advancement. The pre- and post-operative CT scans were compared with respect to pre-established landmarks. Linear distances, cross-sectional areas, and volumes were measured using 3-dimensional CT scan reconstructions.

Results: For the linear distances measured, a statistically significant difference was found when comparing the pre- and post-operative measures of the narrowest part of the nasopharynx and the narrowest part of the retropalatal airway space ($P = 0.001$ and 0.026 , respectively). Retropalatal cross-sectional areas, nasopharyngeal cross-sectional areas, and the volumetric assessment of the nasopharyngeal space showed no statistically significant differences when comparing pre- and post-operative scans ($P < 0.05$). Mean changes in the measures did not differ over time (pre- and post-operative) depending on whether there was a prior history of cleft palate repair.

Conclusions: Although structural modifications of the pharyngeal space are inherent to maxillary advancement, its surface area and volume do not significantly change. The use of 3-dimensional reconstruction using CT scans should be the first choice for evaluation of the upper airway. (*Plast Reconstr Surg Glob Open* 2020;8:e3232; doi: [10.1097/GOX.0000000000003232](https://doi.org/10.1097/GOX.0000000000003232); Published online 9 November 2020.)

INTRODUCTION

Cleft lip and palate (CLP) are common congenital anomalies with a prevalence of 1–2 births per 1000.¹ When a cleft palate (CP) is present, the muscular insertions on the soft palate are abnormally configured. Surgery is aimed not only at closing the palatal defect but also at correcting this abnormal configuration by establishing continuity and proper muscular orientation.²

Abnormal facial growth is commonly seen in patients with CP.³ Repair of CP induces palatal scarring, which restricts growth of the maxilla in all directions, resulting in iatrogenic maxillary insufficiency. Correction of this maxillary retrusion is carried out 60% of the time in these patients,⁴ with the Le Fort I osteotomy being undertaken in almost 84% of them.⁵

During maxillary advancement (MA), there is concomitant advancement of the soft palate. This can lead to an increase in the space between the velum and the posterior pharyngeal wall. In patients without prior CP repair, this gap is usually compensated for by the lateral pharyngeal walls and the palatal musculature. Patients with CP are at a higher risk of velopharyngeal insufficiency because their scarred palatal musculature restricts this innate compensatory mechanism.^{6,7} So while orthognathic surgery has a potentially beneficial effect on speech due to the reestablishment of maxillomandibular equilibrium, it may contribute to the worsening of pre-existing hypernasality in patients with CP.⁸

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The use cephalograms in evaluating changes of airway size and shape MA has been extensively described.⁹ However, with recent advances in orthognathic surgery, there is an increased need for more detailed and precise imaging to help in surgical planning and to monitor response to treatment. Computerized Tomographic (CT) scans have the advantage of imaging structures in 3 dimensions, evaluating sagittal depth, transverse diameter, and pharyngeal airway volume. CT reconstructions have become crucial in surgical planning and yield superior surgical outcomes.^{10–12}

The purpose of this study was to document changes in airway anatomy, as measured on 3-Dimensional (3D) CT scans after Le Fort 1 MA. Additionally, differences in airway anatomy in patients with and without CP were compared. It was hypothesized that in patients undergoing MA, there are modifications in the structural anatomy of the naso- and- oropharynx. But more specifically, it was hypothesized that although the dimensions of the pharyngeal space are modified, its surface area and volume do not change significantly.

PATIENTS AND METHODS

This was a retrospective single center cohort study of patients with and without CP who were treated with Le Fort 1 MA at our institution. This study was approved by the ethics committee at Sainte-Justine University Affiliated Hospital in Montreal.

Subjects

The inclusion criteria stipulated that subjects must have undergone: 1) Le Fort 1 MA at Sainte-Justine Hospital between 2012 and 2018, and 2) pre- and post-operative 3D CT scans from the top of the cranium to the base of the epiglottis. Both patients with and without a history of repaired CP were included. Patients aged under 16 years, and those who underwent craniofacial procedures that did not include Le Fort 1 MA or were lacking pre-operative or post-operative CT scans were excluded. Any syndromic patient was excluded.

Surgical Procedure

The surgical procedures for all subjects included in this study were done by the same plastic surgeon (D.B). All patients underwent a Le Fort 1 MA. Of the 44 patients included, 35 underwent concomitant bilateral sagittal split osteotomy setbacks.

Image Acquisition

All patients undergoing orthognathic surgery would undergo pre-operative CT scans for virtual surgical planning. These were all done within a year of the surgery, with most being between 1 and 3 months pre-operatively. Post-operative CT scans are routinely done at our institution. The most common time point for these was 3 days post-operatively (range, 1–365).

All subjects in the study underwent CT scans in the supine position with the head and neck in a neutral position and with the Frankfurt horizontal plane perpendicular

to the ground. Images were acquired along the axial plane from the top of the cranium to the base of the epiglottis. The software used to reconstruct the images was Voxar. It allowed the following images to be computerized: 1) the original axial view, 2) coronal view, 3) sagittal view, and 4) 3D reconstruction.

Image Analysis

One author (ES) evaluated all CT images by identifying landmarks and by measuring linear distances, cross-sectional areas, and the nasopharyngeal volume. A second independent evaluator, who is a radiologist specialized in head and neck imaging (RJ), evaluated a subset of the CT images.

The landmarks and measurements were the same as those used by Gokce et al.,¹³ Jakobson et al.,¹⁴ and Mason et al.¹⁵ The linear distances were calculated on the midsagittal plane through the nasal septum. The pre- and post-operative upper airway cross-sectional areas (CSAs) were studied at 2 levels identified on the midsagittal plane. On the corresponding axial image, the perimeter of the airway was traced with the cursor, and CSA was computed. Finally, to calculate the nasopharyngeal volume (NPV), the boundaries were set in the sagittal and coronal views, and the corresponding axial view was obtained. The perimeter of the airway was traced with the cursor at 5 levels between the upper and lower boundaries, and the NPV was automatically calculated.^{13,14} The landmarks and measures are described in Table 1 and Figures 1–6.

The technique used for evaluation of the magnitude of maxillary advancement (MMA) was based on those used by Abramson et al,¹⁶ Lye et al,¹⁷ and Turvey et al.¹⁸ For MA and position, the true horizontal axis was defined as the sella-nasion line rotated 6 degree clockwise from the sella turcica (S). The posterior vertical reference line was a line passing through S and perpendicular to the true horizontal. The anterior vertical reference line was a line passing through point A (most concave point of anterior maxilla) and perpendicular to the true horizontal. The distance between anterior vertical reference line and posterior vertical reference line was measured before and after MA and is referred to as the MMA (in millimeters).

Data Analysis

Data analysis was done using SPSS Statistics, version 25. A 2-way mixed ANOVA was used to compare the mean differences between the groups (CP versus Non-CP), the mean differences in the pre- and post-operative measurements (within-groups), and to understand if there was an interaction between the group and surgery variables. That is, whether the differences seen over time (pre- and post-operative) varied depending on whether there was a history of prior CP repair.

A sub-group analysis was performed comparing those who underwent maxillomandibular surgery (MA + bilateral sagittal split osteotomy) with those who underwent MA alone. A Mann-Whitney U test was used to assess differences in RPa, RPa AP, and RPa LL between these two groups. Interrater reliability was assessed using an inter-class correlation coefficient. A mean value of $P < 0.05$ was considered statistically significant for all analyses.

Table 1. Landmarks, Linear Distances, Cross Sectional Areas, and Volumetric Space Assessed on CT Scans

| | Description | Definition |
|-----------|---|---|
| Landmarks | | |
| PNS | Posterior nasal spine | The point on the retropalatal anterior pharyngeal wall, just behind the posterior nasal spine (PNS) point |
| UPW | Upper pharyngeal wall | The intersection point of posterior pharyngeal wall and the line from basion (B) to PNS |
| NPW | Narrowest pharyngeal wall | The intersection of the posterior pharyngeal wall to the narrowest space of the retropalatal region |
| RV | Retro velar | The intersection of the posterior surface of the soft palate to the narrowest space of the retropalatal region |
| Distances | | |
| PNS-UPW | Narrowest part of the nasopharynx | The distance from the posterior nasal spine to the horizontal counterpoint on the posterior pharyngeal wall |
| RV-NPW | Narrowest part of the retropalatal airway space | The narrowest distance between the soft palate (SP) to its horizontal counterpoint on the posterior pharyngeal wall, representing the minimal airway dimension at the retropalatal region |
| VL | Velar length | Distance between the posterior border of the hard palate (PNS) and center of the uvula |
| VT | Velar thickness | Distance from the velar knee to the velar dimple |
| RPa AP | Anteroposterior distance at the RPa | Anteroposterior distance along the retropalatal cross-sectional area |
| RPa LL | Latero-lateral distance at the RPa | Latero-lateral distance along the retropalatal cross-sectional area |
| Areas | | |
| NPa | Nasopharyngeal cross-sectional area | Along the horizontal plane of PNS-UPW |
| RPa | Retropalatal cross-sectional area | Along the horizontal plane of RV-NPW |
| Volume | | |
| NPV | Nasopharyngeal volume | Airway formed between the PNS-UPW and the RV-NPW planes |

RESULTS

A total of 44 patients (24 men, 20 women) underwent MA at an average age of 20.3 years (range, 15–29 years). Twenty-three subjects had a prior CP repair. Of the 23 subjects, 6 had bilateral cleft lip and palate, 8 and 5 had left and right unilateral cleft lip and palate respectively, 1 had an isolated CP, and 3 had submucosal CP.

When comparing the average age at the time of surgery, there was no statistically significant difference between the two groups ($P = 0.392$). Looking at gender

distribution, there was a clear discrepancy between the CP and Non-CP groups. There was a higher proportion of males in the CP group (73.9%), whereas that of females in the non-CP group was higher (66.6%), a difference that was statistically significant ($P = 0.007$) (Table 2).

The mean maxillary advancement for the CP group was 6.2mm, while for the non-CP group it was 4.2mm. This difference was not statistically significant ($P = 0.571$) (Table 2).

The average delay between the pre-operative scan and surgery was 74.4 (range, 28–208) for the CP group and 99.5

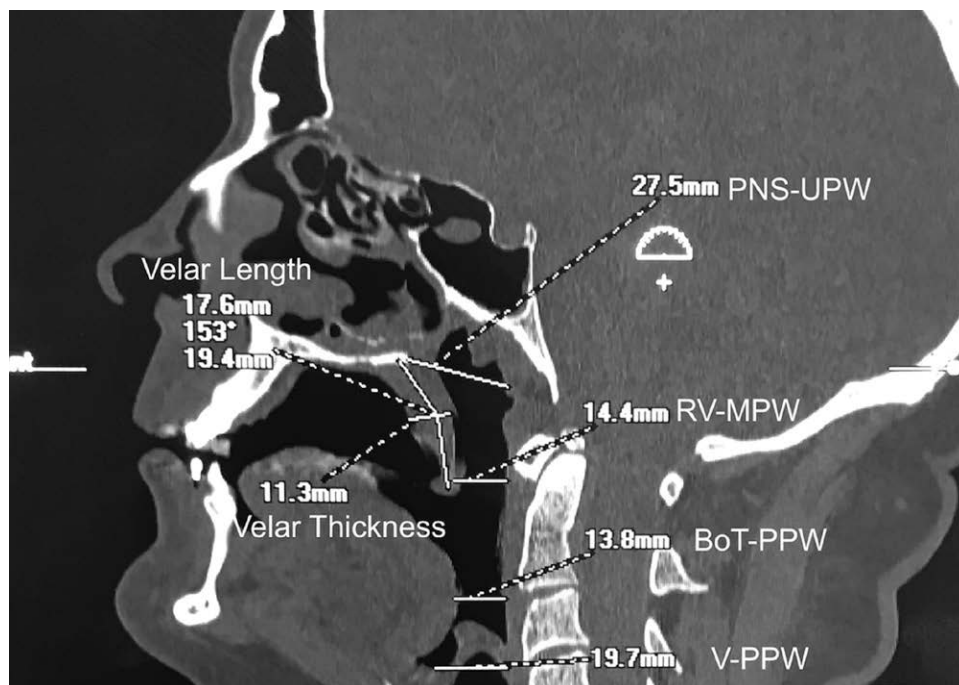


Fig. 1. Linear distances assessed on sagittal reconstruction, using a CT scan.

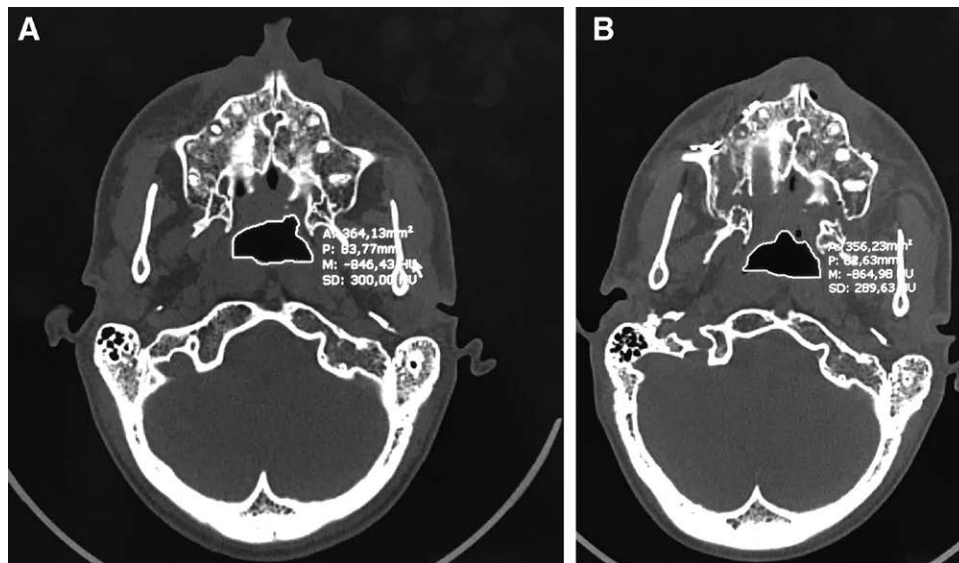


Fig. 2. CSA assessments on CT scans. A, Example of pre-operative nasopharyngeal CSA assessment. B, Example of post-operative nasopharyngeal CSA assessment.

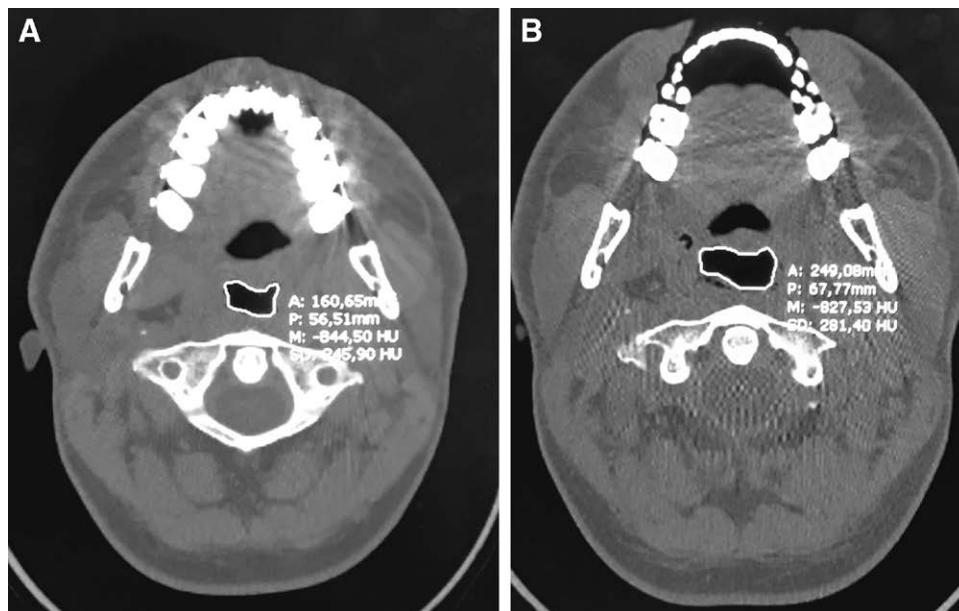


Fig. 3. CSA assessments on CT scans. A, Example of pre-operative retropalatal CSA assessment. B, Example of post-operative retropalatal CSA assessment.

(range, 20–390) for the non-CP group. For timing of the post-operative scans, the mean number of days for the CP group was 21.7 (range, 1–365) and for the non-CP group it was 12.5 (range, 1–128). These differences were not statistically significant ($P = 0.533$ and 0.808 , respectively).

For the linear distances computed, PNS-UPW distance went from 25.1 mm in the pre-operative period to 28.5 mm post-operatively ($P = 0.001$). Of the remaining linear distances measured, a statistically significant difference was found when comparing the pre- and post-operative measures of the RV-NPW (6.5 mm versus 7.6 mm, $P = 0.026$), VT (8.2 mm versus 9.6 mm, $P = 0.031$) and RPa AP (7.5 mm versus 8.6 mm, $P = 0.013$) distances (Table 3).

After surgery, no statistically significant changes in the cross-sectional areas were recorded. No change was observed for the NPa (pre: 375.2 mm^2 versus post: 370.4 mm^2 , $P = 0.435$) and RPa (pre: 129.8 mm^2 versus post: 145.7 mm^2 , $P = 0.525$). There was also no statistically significant difference in the pre- and post-operative measurements of the NPV (4.1 cm^3 versus 4.3 cm^3 , $P = 0.401$) (Table 4).

The main effect of palatal repair (CP versus Non-CP) showed that there was only a statistically significant difference for the PNS-UPW and NPa measures ($P = 0.045$ and $P = 0.04$, respectively). There were no statistically significant interactions between time and group. That is, mean

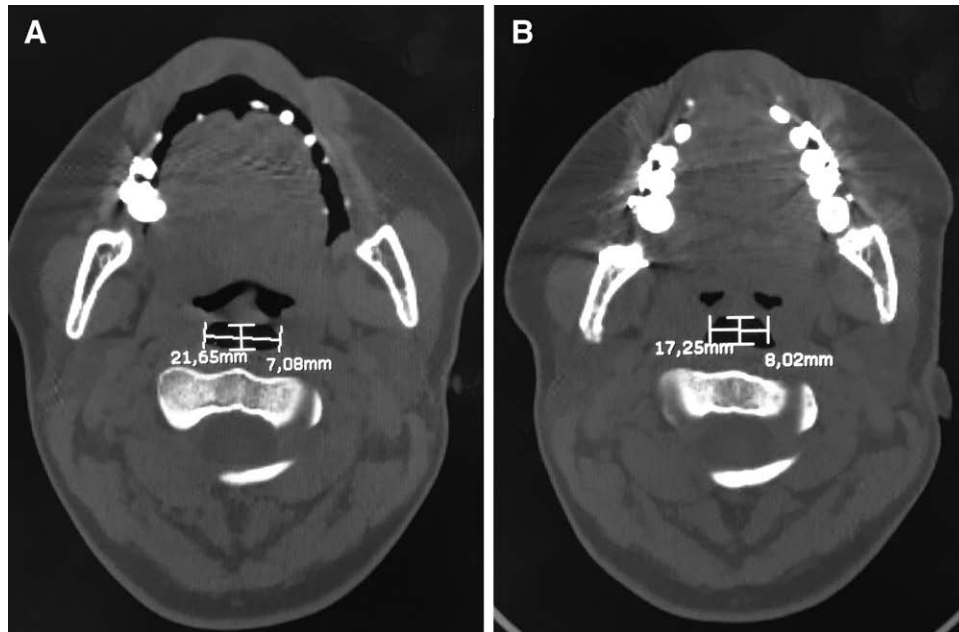


Fig. 4. CSA assessments on CT scans. A, Example of pre-operative AP and LL distances along the RPa. B, Example of post-operative AP and LL distances along the Rpa.

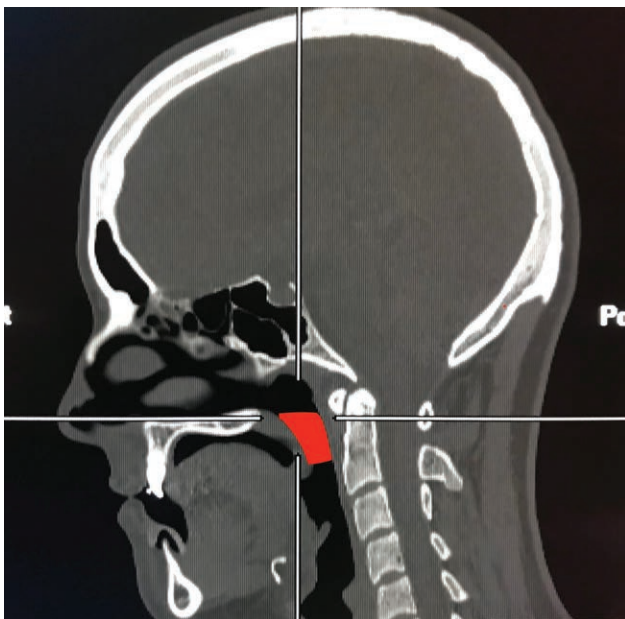


Fig. 5. Sagittal view of the nasopharyngeal volume assessed.

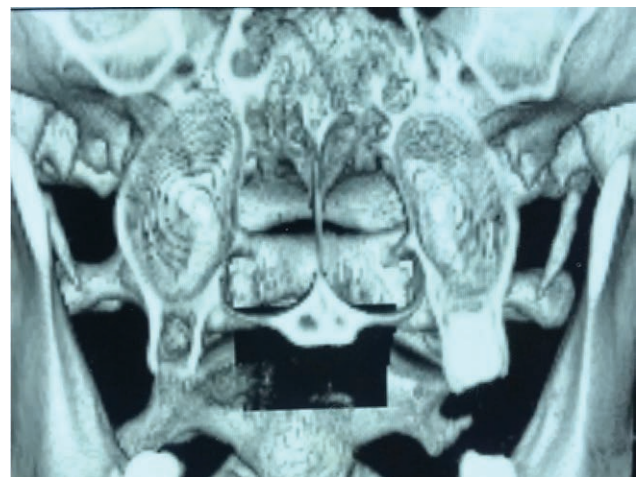


Fig. 6. Coronal view of the nasopharyngeal volume assessed.

changes in the measures did not differ over time (pre- and post-operative) depending on whether there was prior history of CP repair.

Differences in pre-to post-operative change for the RPa, RPa AP, and RPa LL measures between those who underwent MA with or without concomitant mandibular repositioning were computed. For the RPa LL distance change, a statistically significant difference was found between the mean increase of 2.98mm in the MA group alone and the mean decrease of 1.77mm in the maxilomandibular surgery group ($P = 0.027$). No change was

noted between the two groups for the RPa and RPa AP measures ($P = 0.104$ and $P = 0.647$, respectively).

On all 88 scans (44 patients), measures were assessed by a single evaluator (E.S.). A second independent evaluator (R.J.) used the same technique to measure 20 randomly selected scans (10 patients). The interclass correlation coefficient was 0.989.

DISCUSSION

The purpose of this study was to evaluate the changes to the velopharyngeal anatomy after MA using 3D CT scans. In addition, the differences in these measures between patients with and without prior CP repair were compared. Several studies have measured surface areas and volumes of the nasopharynx, oropharynx, and hypopharynx

Table 2. Characteristics of Patients Included

| | Total (n = 44) | CP (n = 23) | Non-CP (n = 21) | P |
|------------|----------------|-------------|-----------------|---------------|
| Age (y)* | 20.3 | 20.6 | 19.9 | 0.392 |
| Gender† | | | | |
| Male (%) | 54.5 | 73.9 | 33.3 | 0.007‡ |
| Female (%) | 45.5 | 26.1 | 66.6 | |
| MMA (mm) | 5.21 | 6.18 | 4.24 | 0.571 |

*Independent Samples Student's *t*-test was performed to compare means for normally distributed variables.

†Chi-square was used to measure associations between frequencies.

‡Statistically significant value ($P < 0.05$).

Table 3. Linear Distance Analysis

| | Pre-operative | Post-operative | P (within group) | P (between groups) | P (interaction) |
|----------------------------|---------------|----------------|------------------|--------------------|-----------------|
| PNS-UPW (mean), mm | 25.1 ± 5.6 | 28.5 ± 5.4 | | | |
| CP | 26.6 ± 5.3 | 30.0 ± 5.6 | | | |
| Non-CP | 23.5 ± 5.5 | 27.0 ± 4.9 | 0.001 | 0.045 | 0.943 |
| RV-NPW (mean), mm | 6.5 ± 4.3 | 7.6 ± 5.1 | | | |
| CP | 6.1 ± 5.0 | 7.4 ± 6.1 | | | |
| Non-CP | 7.0 ± 3.4 | 7.9 ± 3.8 | 0.026 | 0.621 | 0.608 |
| Velar length (mean), mm | 32.3 ± 7.6 | 33.5 ± 9.4 | | | |
| CP | 31.1 ± 7.6 | 31.3 ± 10.4 | | | |
| Non-CP | 33.8 ± 4.1 | 35.8 ± 7.6 | 0.284 | 0.096 | 0.417 |
| Velar thickness (mean), mm | 8.2 ± 2.0 | 9.6 ± 4.4 | | | |
| CP | 8.1 ± 2.0 | 9.7 ± 4.3 | | | |
| Non-CP | 8.3 ± 1.9 | 9.5 ± 4.6 | 0.031 | 0.980 | 0.797 |
| RPa LL (mean), mm | 17.2 ± 9.5 | 16.4 ± 9.3 | | | |
| CP | 14.7 ± 10.8 | 14.0 ± 10.8 | | | |
| Non-CP | 20.0 ± 6.7 | 19.0 ± 6.8 | 0.320 | 0.058 | 0.817 |
| RPa AP (mean), mm | 7.5 ± 5.0 | 8.6 ± 5.0 | | | |
| CP | 7.4 ± 6.6 | 8.4 ± 6.5 | | | |
| Non-CP | 7.7 ± 2.4 | 8.8 ± 2.7 | 0.013 | 0.805 | 0.921 |

Two-way mixed ANOVA was used to compare the mean differences between the groups (CP versus Non-CP) and the mean differences in the pre- and post-operative measurements (within groups). The interaction *P* value reflects whether differences seen over time (pre- and post-operative) varied depending on the groups. Values in boldface indicate statistical significance ($P < 0.05$).

Table 4. Area and Volumetric Analysis

| | Pre-operative | Post-operative | P (within group) | P (between groups) | P (interaction) |
|-----------------------------|---------------|----------------|------------------|--------------------|-----------------|
| NPa (mean), mm ² | 375.2 ± 120.6 | 370.4 ± 142.6 | | | |
| CP | 416.9 ± 111.4 | 424.8 ± 137.4 | | | |
| Non-CP | 329.5 ± 115.8 | 310.8 ± 125.9 | 0.751 | 0.04 | 0.435 |
| RPa (mean), mm ² | 129.8 ± 102.1 | 145.7 ± 99.9 | | | |
| CP | 138.0 ± 127.0 | 147.3 ± 119.5 | | | |
| Non-CP | 120.8 ± 67.3 | 143.9 ± 75.5 | 0.410 | 0.723 | 0.525 |
| NPV (mean), cm ³ | 4.1 ± 2.3 | 4.3 ± 2.4 | | | |
| CP | 3.9 ± 2.5 | 4.4 ± 2.5 | | | |
| Non-CP | 4.2 ± 2.0 | 4.3 ± 2.3 | 0.291 | 0.857 | 0.401 |

Two-way mixed ANOVA was used to compare the mean differences between the groups (CP versus Non-CP) and the mean differences in the pre- and post-operative measurements (within groups). The interaction *P* value reflects whether differences seen over time (pre- and post-operative) varied depending on the groups. The value in boldface indicates statistical significance ($P < 0.05$).

following MA using CT scans.^{11,19-22} However, there is no clear consensus as to the morphological changes seen following MA.^{11,21,22}

MA is performed when patients have completed their maxillofacial growth to obtain reliable and predictable results.⁹ Average age of the combined groups at the time of surgery was 20.3 years. Schendel et al.²² demonstrated progressive enlargement of the posterior airway in childhood until age 15. Given that all included patients were older than 16 years, this possible source of bias was eliminated. There was no difference in age at the time of surgery between the CP and non-CP groups.

Maegwa et al. separated patients into 1 of 2 categories based on the amount of maxillary advancement performed. Advancements up to 10 mm were associated with

maintaining baseline or improving speech intelligibility, whereas advances above 10 mm were associated with decreased intelligibility and hypernasality.²³⁻²⁵ Despite these described complications, there are many benefits to MA. Apart from aesthetic facial improvement, this surgery has also been proven to improve mood, affect, social interactions, and speech ability (Figs. 7, 8).²⁶ The mean maxillary advancement for the CP group was 6.18 mm and 4.24 mm for the non-CP group. With a relatively limited amount of advancement in the present study compared with up to 12.4 mm in some,²⁷ significant changes in surface areas and volumes were not expected.

The literature assessing structural airway changes in patients undergoing MA is limited. The majority of published studies focus primarily on the structural changes to

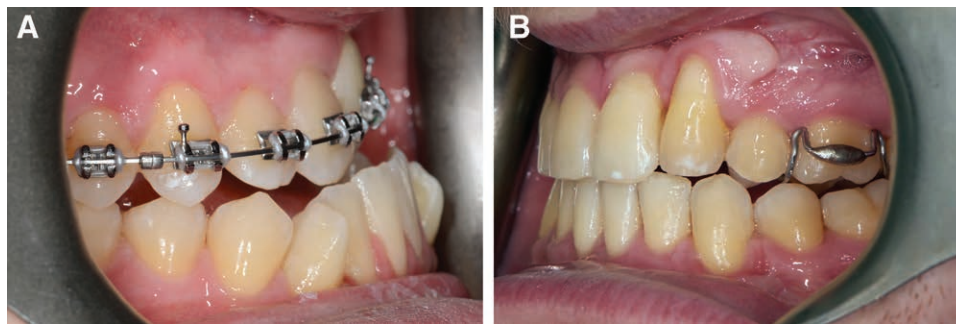


Fig. 7. Pre- and postoperative patient photographs. A, Pre-operative occlusion of a patient with a prior history of repaired CP. B, Post-operative occlusion of a patient with a prior history of repaired CP.

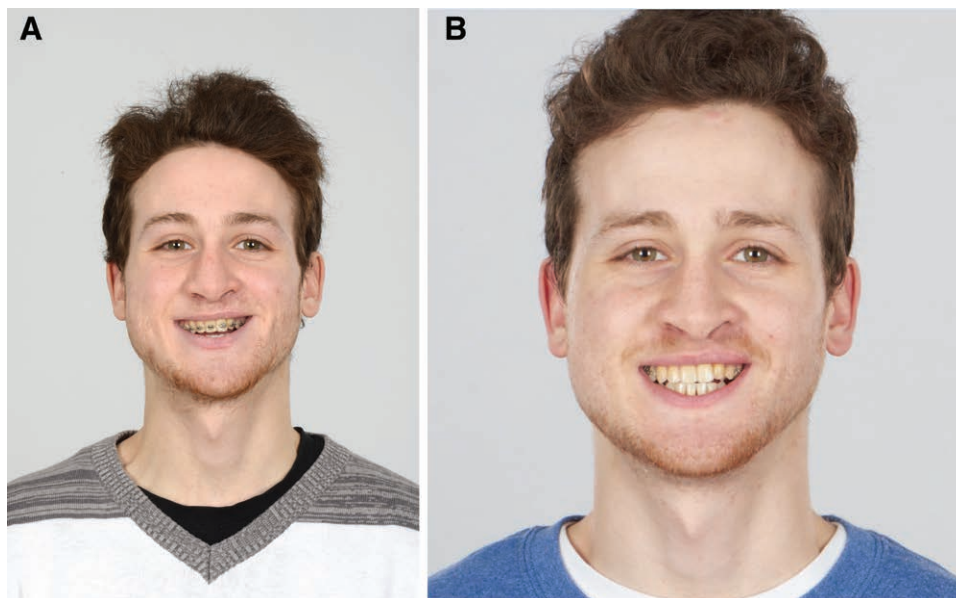


Fig. 8. Pre- and postoperative patient photographs. A, Pre-operative photograph of a patient with a prior history of repaired CP. B, Post-operative photograph of a patient with a prior history of repaired CP.

the airway and their impact on patients with obstructive sleep apnea.^{11,13,16,28,29} To the best of our knowledge, the anatomical changes of the velum studied on CT scans have yet to be reported. Patients with no history of CP have the ability to compensate for the structural changes following MA, which prevents any adverse effects on velopharyngeal closure function and speech.³⁰ Cephalometric analyses of these changes have been reported but published results are inconsistent. Ko et al. described these changes as increases in nasopharyngeal depth, VL, and velar angle, and a decrease in VT.³¹ Wu et al. reported an increase in VL with no change in VT.³² In this study, the anatomical changes to the velum, VL and VT, were assessed using CT scans. Although VL did show a trend toward an increase from the pre-operative period to the post-operative period, this change was not significant. This is consistent with the reports by Ko et al.³¹ and Heliövaara et al.³³ Furthermore, the difference in VL from the pre-to the post-operative period was independent of whether or not patients had a prior CP repair. A significant increase was noted when comparing the pre- and post-operative measures of VT.

While a decrease in VT due to velar stretch may have been expected, the increase noted may be attributed to post-operative edema, as most scans were completed in the acute post-operative period.

We found a statistically significant increase in the linear distance RV-NPW ($P = 0.026$) following MA. Similarly, the RPa AP distance significantly increased following MA ($P = 0.013$). Chang et al.¹¹ and Gokce et al.¹³ both described similar findings reporting an increase in the AP distance between the soft palate and posterior pharyngeal wall. Gokce et al.¹³ also reported a statistically significant increase in the PNS-UPW distance, which was consistent with our findings. These changes are attributed to anterior displacement of the maxilla and the subsequent pull on the velum and velopharyngeal muscles following the Le Fort I osteotomy.¹³

It was thought that with advancement of the maxilla and the velum, the lateral pharyngeal walls would compensate to maintain an unchanged overall area and volume. For instance, Kumer et al. used videofluoroscopy and reported increased motion of the lateral pharyngeal walls

following MA.³⁴ The LL distance at the level of RV-NPW was used to assess this change. Although not statistically significant, a trend toward a decrease was noted. This is however not consistent with other studies reporting an increase in the LL distance.^{13,28,29} We then compared those who underwent exclusive MA with those who underwent MA with concomitant mandibular setback and noticed a significant difference in the RPa LL distance. While those who underwent exclusive MA saw an average increase of 2.98 mm, those who underwent a maxillomandibular surgery actually saw an average decrease of 1.77 mm. Degerliyurt et al.²¹ led a study comparing the structural airway changes between patients who underwent exclusive mandibular setback and patients who underwent maxillomandibular surgery. They found that lateral pharyngeal narrowing was only statistically significant in the mandibular setback group. They attributed this difference to the displacement of the medial pterygoid muscles caused by the mandibular setback.³⁵ Our findings are thus similar and show that maxillary surgery might counteract the reduction in lateral width, which is an effect of mandibular setback.³⁶

Although changes in AP and LL distances were seen, the overall surface area measures did not change significantly in our sample. Similarly, Jakobson et al. found no statistically significant change in VP CSA after MA.¹³ Abramson et al. did report an increase in the minimum VP CSA after MA.¹⁶ However, their mean maxillary advancement was of 9.2 mm, which is significantly higher than that of the present study. The relatively limited MMA in our study perhaps explains the lack of a statistically significant change when comparing the pre- and post-operative measures. When analyzing the difference in NPa between the two study groups, it was significantly smaller in the non-CP group both pre- and post-operatively. This change was likely a reflection of the significant difference in the PNS-UPW distance between the two study groups.

With respect to NPV, no statistically significant difference was observed. Chang et al.¹¹ and Gokce et al.¹³ both reported statistically significant increases in NPV following MA surgery. Jakobson et al.¹⁴ found no significant change in NPV following MA but rather reported a trend toward a decrease. Aras et al. led a study using CT scans to measure and compare total airway volume in patients with and without CP. Although there was a decrease in the volume in patients with CP due to the scar tissue contracture, it was not statistically significant.²⁰

Several limitations are worth noting in this study. First, due to its retrospective nature, there were no instructions given to the patients during the CT scans. Therefore, there was no standardization of verbal guidance in terms of holding their breath, swallowing, or proceeding normally. Similarly, CT scans offer only a static evaluation of a dynamically functional structure. So, while airway size, shape, and dimensions may be an indicator for residual velopharyngeal insufficiency,^{37–39} they do not substitute for a dynamic assessment of velopharyngeal closure.

Another limitation is that not all scans were performed at the same time pre- and post-operatively. Due to the acute post-operative timing of the scans, the presence of

edema may have introduced bias to the results. Having the scans done at standardized time frames minimizes bias and makes the obtained results more comparable. Finally, the procedures were not uniform amongst the 44 included patients. While the majority underwent maxillomandibular surgery, a subset of patients underwent exclusive MA. The mixture of data may have introduced certain bias to the results.

CONCLUSIONS

The goal of the present study was to identify useful anatomic and morphologic changes to the velopharyngeal space following MA. The use of 3D reconstruction using CT scans should be the first choice for evaluation of the upper airway. Not only does it provide the surgeon with an understanding of the underlying anatomical structures during pre-operative planning, it also allows for assessment of structural changes following surgery. These changes serve as key indicators for functional outcomes. Future studies should correlate these anatomic results to dynamic velopharyngeal function assessments and development of velopharyngeal insufficiency.

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PATIENT CONSENT

The patient provided written consent for the use of his image.

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