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Analysis of Skeletal and Airway Changes Following Anterior Maxillary Distraction in Cleft Patients: A CBCT Study

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Abstract

Aim: This study aimed to evaluate the skeletal, soft tissue, and airway changes following anterior maxillary distraction in cleft lip and palate (CLP) patients using cone-beam computed tomography (CBCT). The objective was to assess the impact of distraction osteogenesis on pharyngeal airway volume, maxillary sinus dimensions, and facial aesthetics.
Methods: Thirty patients, aged 12–18, with maxillary hypoplasia secondary to CLP, underwent anterior maxillary distraction using a tooth-borne modified Hyrax appliance. Preoperative and postoperative CBCT scans were obtained and analyzed for changes in nasopharyngeal and oropharyngeal volumes, maxillary sinus dimensions, and cephalometric parameters. Hard tissue changes included ANB angle, PNS-ANS distance, and U1 to A-Pog measurements, while soft tissue assessment focused on upper lip length, protrusion, and position relative to E-line and S-line. Statistical analysis was conducted using paired t-test, with a significance level of $P<0.05$.
Results: Significant improvements were observed in nasopharyngeal volume (2.66 cm^3 to 4.84 cm^3, $P<0.001$) and total pharyngeal volume (12.97 cm^3 to 15.64 cm^3, $P<0.001$), indicating enhanced airway patency. The ANB angle increased from -3.60° to 2.60° ($P<0.001$), confirming skeletal advancement. Maxillary sinus volumes increased bilaterally ($P<0.001$), and soft tissue changes showed improved lip support and projection.
Conclusion: AMD using a modified Hyrax appliance significantly enhanced airway function, skeletal structure, and facial aesthetics in CLP patients. CBCT proved valuable in quantifying these changes. This study reinforces the clinical effectiveness of distraction osteogenesis for maxillary advancement and airway improvement, providing both functional and aesthetic benefits.

Keywords: Distraction Osteogenesis, Pharyngeal Airway Volume, Maxillary Hypoplasia, Skeletal Advancement

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Background

Distraction osteogenesis (DO) has emerged as a transformative technique in managing craniofacial deformities, particularly in patients with cleft lip and palate (CLP). First introduced by Codivilla in 1905, DO was initially used for limb lengthening, but its application in maxillofacial surgery has since revolutionized the treatment of severe maxillary hypoplasia (1). Ilizarov further advanced the field by establishing the biological principles of DO, emphasizing the "law of tension-stress effect," which facilitates the regeneration of both hard and soft tissues (2). This technique has proven particularly beneficial for CLP patients, who often present with significant maxillary deficiencies that are challenging to address with conventional orthognathic surgery (3,4).

The application of DO in craniofacial surgery began in the 1970s, with Snyder's pioneering work on mandibular lengthening in canines (5). Subsequent advancements by Michieli and Miotti and Kutsevliak and Sukachev demonstrated the feasibility of intraoral devices for maxillary distraction, paving the way for its clinical use in humans (6,7). In CLP patients, DO offers a stable and effective solution for correcting maxillary hypoplasia, which is often associated with functional and aesthetic impairments, including obstructive sleep apnea and midface retrusion (8,9).

Cone-beam computed tomography (CBCT) has become an indispensable tool in evaluating craniofacial structures, providing high-resolution three-dimensional (3D) images that allow for precise assessment of hard and soft tissue changes (10). CBCT has been widely used to study the effects of DO on pharyngeal airway dimensions, maxillary sinus volume, and skeletal and soft tissue profiles (11,12). Studies have demonstrated the utility of CBCT in assessing airway changes following maxillary advancement, highlighting its role in improving both functional and aesthetic outcomes (13,14).

This study evaluated the preoperative and postoperative changes in pharyngeal airway dimensions, hard tissue, and soft tissue structures in CLP patients undergoing anterior maxillary distraction using CBCT. By analyzing these changes, we seek to provide further evidence of the efficacy of DO in improving both functional and aesthetic outcomes in this patient population.

Methods

Study Design and Sample Selection

This study was conducted on 30 patients (aged 12–18) diagnosed with maxillary hypoplasia secondary to cleft lip and palate (CLP). The study included 18 males and 12 females. This gender distribution was considered to ensure a representative sample for evaluating skeletal and airway changes following anterior maxillary distraction. The sample size of 30 patients was determined based on statistical power analysis, previous literature, and feasibility constraints. A power calculation assuming a significance level of 0.05, power of 80%, and an expected effect size of 0.8 indicated that a minimum of 25–30 patients was sufficient to detect meaningful skeletal and airway changes.

Patients included had either unilateral (UCLP) or bilateral cleft lip and palate (BCLP), while cases with isolated cleft palate or significant soft palate involvement were excluded to maintain a homogeneous sample for skeletal and airway analysis. The inclusion criteria comprised patients with completed maxillary growth, severe maxillary hypoplasia, negative overjet, and Cl III malocclusion with a normal mandible. Patients undergoing secondary alveolar bone grafting were also excluded to avoid variability in skeletal response. All patients were treated with anterior maxillary distraction using a tooth-borne modified Hyrax appliance. The institutional ethics committee approved the study, and informed consent was obtained from all participants or guardians (YUEC 198/5/12/2013).

Armamentarium

The primary tools used in this study included the Planmeca ProMax® 3D Mid CBCT unit (Planmeca Oy, Helsinki, Finland) for preoperative and postoperative imaging, and Planmeca Romexis® software for image processing and CBCT analysis. Data was processed and analyzed using a standard desktop computer (Figure 1). A modified Hyrax tooth-borne appliance was custom-fabricated for each patient to facilitate anterior maxillary distraction.

Preoperative Procedure

The anterior maxillary distraction procedure was performed under general anesthesia with naso-endotracheal intubation. A horizontal maxillary vestibular incision was made from the first molar to the contralateral first molar. The mucoperiosteum was reflected to expose the osteotomy site, and a buccal linear osteotomy was performed above the apices of the maxillary teeth. The lateral nasal wall was cut using a small osteotome, and the nasal septum was transected at its base. A vertical interdental osteotomy was performed, and the anterior maxilla was down-fractured and mobilized while preserving the palatal mucosal pedicle. The prefabricated modified Hyrax appliance was then fitted and cemented to the selected teeth (Figure 2). The appliance was activated at a rate of 1 mm/day (5 turns of the key) to achieve the desired distraction.

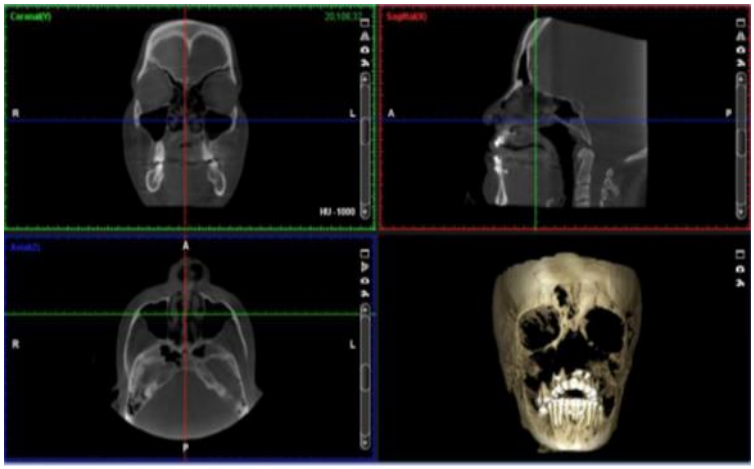


Figure 1: Preoperative CBCT image illustrating the initial skeletal and airway conditions of a patient with maxillary hypoplasia secondary to cleft lip and palate (CLP).



Figure 2: tooth-borne modified Hyrax appliance used for anterior maxillary distraction in CLP patients.

Postoperative Assessment

Postoperative CBCT scans were obtained six months after the distraction procedure using the same protocol as the preoperative scans. The images were analyzed using Planmeca Romexis® software to assess volumetric changes in the nasopharynx, oropharynx, maxillary sinuses, and hard and soft tissue structures. Hard tissue landmarks such as sella (S), nasion (N), A point (A), and B point (B) were recorded, along with soft tissue landmarks including subnasale (Sn), labrale superius (Ls), and soft tissue pogonion (Pg).

Data Analysis

Volumetric measurements of the pharyngeal airway and maxillary sinuses were performed using predefined anatomical boundaries. Cephalometric analysis was conducted to evaluate changes in hard tissue parameters such as ANB angle, PNS-ANS distance, and U1 to A-Pog. Soft tissue parameters were also measured, including upper lip length, protrusion, and position relative to the E-line and S-line. Statistical analysis was performed using paired t-tests to compare preoperative and postoperative measurements at $P<0.05$, considered statistically significant. The Shapiro-Wilk test was performed on all continuous variables to assess the normality of the data distribution. The results indicated that most of the variables followed a normal distribution ($P>0.05$), allowing for parametric statistical tests. Measurement error was assessed using the Dahlberg formula (method error = $\sqrt{(\Sigma d^2/2n)}$) by re-measuring 20% of the CBCT images two weeks apart by the same examiner and the results indicated low measurement error for most parameters (e.g., nasopharyngeal volume, ANB angle, PNS-ANS distance, and soft tissue measurements) and moderate error for oropharyngeal and maxillary sinus volumes, demonstrating overall high reliability in the measurements.

Results

The study's results demonstrated significant changes in pharyngeal airway dimensions, hard tissue, and soft tissue structures following anterior maxillary distraction in patients with maxillary hypoplasia secondary to CLP. The mean preoperative nasopharyngeal volume was 2.66 cm^3, which increased to 4.84 cm^3 postoperatively, with a mean difference of 2.18 cm^3 ($P<0.001$). In contrast, the oropharyngeal volume showed only a minimal increase from 10.31 cm^3 preoperatively to 10.79 cm^3 postoperatively, with a mean difference of 0.48 cm^3 ($P=0.417$), indicating that the oropharyngeal airway was less affected by the procedure. The total pharyngeal volume also increased significantly, from 12.97 cm^3 preoperatively to 15.64 cm^3 postoperatively, with a mean difference of 2.67 cm^3 ($P<0.001$), further supporting the overall improvement in airway dimensions and suggesting that the procedure can enhance overall airway function (Figure 3).

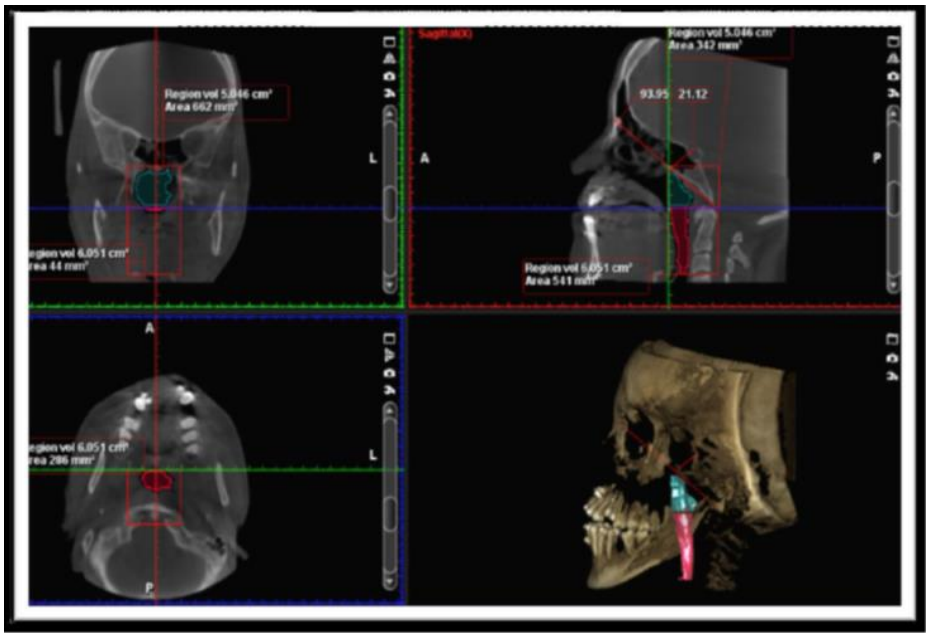


Figure 3: Comparison of preoperative and postoperative CBCT scans demonstrating changes in pharyngeal airway volume following anterior maxillary distraction.

While this study included both unilateral and bilateral cleft lip and palate (UCLP and BCLP) patients, subgroup analyses were not conducted. However, differences in skeletal response between UCLP and BCLP patients may exist due to variations in scar distribution and maxillary growth patterns. Table 1 presents the pre- and post-distraction CBCT volumetric analyses, highlighting significant increases in nasopharyngeal and total pharyngeal volumes, confirming airway improvements following anterior maxillary distraction.

Significant increases were also observed in the maxillary sinus volumes, which are important anatomical structures adjacent to the maxilla. The right maxillary sinus volume increased from 7.06 cm^3 preoperatively to 9.59 cm^3 postoperatively, with a mean difference of 2.53 cm^3 (P<0.001). Similarly, the left maxillary sinus volume increased from 6.41 cm^3 preoperatively to 9.14 cm^3 postoperatively, with a mean difference of 2.73 cm^3 (P<0.001) (Table 1) (Figure 4).

Regarding hard tissue changes, the ANB angle, which reflects the relationship between the maxilla and mandible, increased significantly from -3.60° preoperatively to 2.60° postoperatively, with a mean difference of 6.20° (P<0.001), indicating a substantial improvement in the sagittal relationship between the jaws, correcting the Cl III malocclusion commonly seen in patients with maxillary hypoplasia. Qualitative CBCT assessments suggested that BCLP patients exhibited greater uniform anterior maxillary movement compared to UCLP patients, likely due to symmetrical scar distribution. However, further statistical validation is required. The PNS-ANS distance, representing the extent of the maxillary base, increased from 41.80 mm preoperatively to 49.00 mm postoperatively, with a mean difference of 7.20 mm (P<0.001). This increase reflects the anterior advancement of the maxilla, which is a key objective of the distraction procedure. The U1 to A-Pog angle, which measures the inclination of the upper incisors relative to the A-Pog line, increased from 20.50° preoperatively to 27.50° postoperatively, with a mean difference of 7.00° (P<0.001). The linear measurement of U1 to A-Pog also showed a significant increase, from 0.80 mm preoperatively to 4.90 mm postoperatively, with a mean difference of 4.10 mm (P<0.001), further supporting the anterior movement of the maxilla and the associated dental changes.

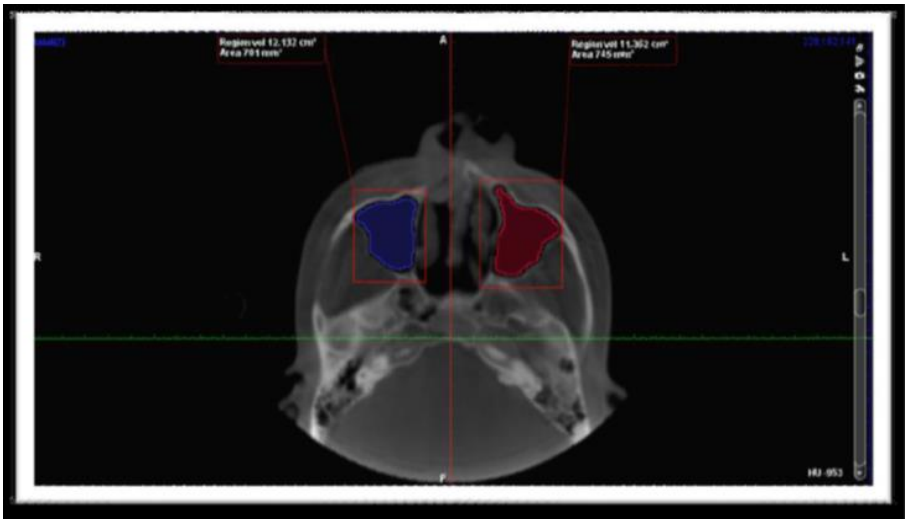


Figure 4: Preoperative and postoperative CBCT scans showing changes in maxillary sinus volume after anterior maxillary distraction.

Table 1: Combined volumetric analysis

Parameter	Pre-distraction mean (cm^3)	Post-distraction mean (cm^3)	Mean difference	P-value
Nasopharynx	2.66±0.58	4.84±0.74	2.18	<0.001
Oropharynx	10.31±1.02	10.79±1.16	0.48	0.417
Total pharyngeal volume	12.97±1.38	15.64±1.42	2.67	<0.001
Maxillary sinus (R)	7.06±1.02	9.59±1.18	2.53	<0.001
Maxillary sinus (L)	6.41±1.21	9.14±1.29	2.73	<0.001

Additionally, the U1 to NF (nasal floor) distance increased from 23.50 mm preoperatively to 25.20 mm postoperatively, with a mean difference of 1.70 mm (P=0.001), indicating that the anterior maxillary dental height increased following the distraction procedure. The U1 to SN (sella-nasion plane) distance increased from 101.60 mm preoperatively to 105.40 mm postoperatively, with a mean difference of 3.80 mm (P=0.025), reflecting the overall anterior movement of the maxilla and its relationship to the cranial base. The Wits appraisal, which assesses the relationship between the maxilla and mandible, improved significantly from -3.40 mm preoperatively to 1.50 mm postoperatively, with a mean difference of 4.90 mm (P<0.001). The skeletal changes observed are summarized in Table 2, which details improvements in the ANB angle, PNS-ANS distance, and U1 to A-Pog measurements, reflecting significant anterior maxillary movement and correction of skeletal discrepancies.

Soft tissue analysis revealed significant improvements in upper lip parameters, which are important for facial aesthetics. The upper lip length increased from 15.50 mm preoperatively to 18.80 mm postoperatively, with a mean difference of 3.30 mm (P<0.001). Upper lip protrusion increased from 1.50 mm preoperatively to 4.50 mm postoperatively, with a mean difference of 3.00 mm (P<0.001), indicating that the upper lip became more prominent following the procedure. This change is particularly important for patients with CLP, who often have retruded upper lips due to maxillary hypoplasia. The distance from the upper lip to the E-line (aesthetic plane) improved from -6.90 mm preoperatively to -2.50 mm postoperatively, with a mean difference of 4.40 mm (P<0.001). Similarly, the distance from the upper lip to the S-line increased from -3.10 mm preoperatively to 0.80 mm postoperatively, with a mean difference of 3.90 mm (P<0.001), further supporting the positive changes in lip positioning and overall facial profile (Figure 5). Table 3 shows significant improvements in upper lip length, protrusion, and position relative to aesthetic planes, reinforcing the aesthetic benefits of anterior maxillary distraction.

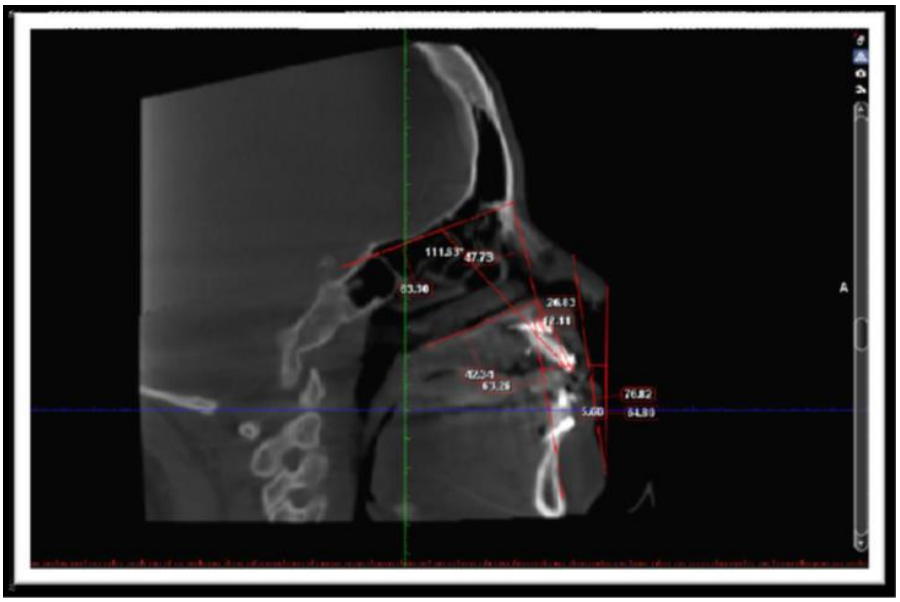


Figure 5: Cephalometric analysis depicting preoperative and postoperative skeletal changes, including ANB angle, PNS-ANS distance, and upper incisor inclination.

Table 2: Combined hard tissue analysis

Parameter	Pre-distraction mean	Post-distraction mean	Mean difference	P-value
ANB (°)	-3.6±1.12	2.6±1.28	6.2	<0.001
PNS-ANS (mm)	41.8±2.40	49.0±2.64	7.2	<0.001
U1 to A-Pog (°)	20.5±2.21	27.5±2.56	7.0	<0.001
U1 to A-Pog (mm)	0.8±0.45	4.9±0.52	4.1	<0.001
U1 to NF (mm)	23.5±1.30	25.2±1.40	1.7	0.001
U1 to SN (mm)	101.6±2.50	105.4±2.60	3.8	0.025
Wits Appraisal (mm)	-3.4±1.20	1.5±1.30	4.9	<0.001

Table 3: Combined soft tissue analysis

Parameter	Pre-distraction mean	Post-distraction mean	Mean difference	P-value
Upper lip length (mm)	15.5± 1.36	18.8± 1.52	3.3	<0.001
Upper lip protrusion (mm)	1.5± 0.68	4.5± 0.74	3.0	<0.001
Upper lip to E-line (mm)	-6.9 ± 1.04	-2.5 ± 1.08	4.4	<0.001
Upper lip to S-line (mm)	-3.1±1.05	0.8±1.12	3.9	<0.001

A young patient with maxillary hypoplasia secondary to cleft lip and palate (CLP) presented with severe midface retrusion, a concave facial profile, negative overjet, and compromised airway function. Preoperative evaluation, including CBCT imaging and cephalometric analysis, revealed restricted nasopharyngeal volume (2.66 cm^3), total pharyngeal volume (12.97 cm^3), and reduced maxillary sinus dimensions. The skeletal analysis indicated a Cl III relationship with an ANB angle of -3.60°, while soft tissue assessment showed a retruded upper lip (upper lip to E-line: -6.90 mm). Given these findings, anterior maxillary distraction (AMD) was planned using a tooth-borne modified Hyrax appliance, which was activated at 1 mm/day following maxillary osteotomy. The patient underwent a six-month consolidation period post-distraction to allow for new bone formation and stabilization (Figure 6).



Figure 6: Pre- and post-distraction clinical images showing improved midface projection, upper lip support, and facial aesthetics in a patient.

Significant improvements in airway volume, skeletal advancement, and soft tissue profile were observed at the six-month postoperative follow-up. CBCT analyses showed a substantial increase in nasopharyngeal volume (4.84 cm^3) and total pharyngeal volume (15.64 cm^3), indicating improved airway patency. The ANB angle improved to 2.60°, confirming effective maxillary advancement, while maxillary sinus volume increased bilaterally. Soft tissue changes included a more prominent upper lip, with lip length increasing from 15.50 mm to 18.80 mm, and improved facial projection. Although overall improvements were seen across the cohort, treatment response may vary depending on the cleft type, as scarring patterns influence skeletal mobility. Future studies should investigate whether UCLP and BCLP patients experience differing rates of skeletal stability and airway enhancement post-distraction. Clinically, the patient exhibited enhanced nasal prominence, a more balanced facial profile, and a stable occlusion with improved overjet, demonstrating the success of anterior maxillary distraction in addressing both functional and aesthetic concerns in cleft lip and palate cases.

Discussion

The findings of this study demonstrated the significant impact of anterior maxillary distraction on pharyngeal airway dimensions, hard tissue structures, and soft tissue aesthetics in patients with maxillary hypoplasia secondary to cleft lip and palate (CLP).

Volumetric Changes in Pharyngeal Airway and Maxillary Sinus

The significant increase in nasopharyngeal volume (mean difference: 2.18 cm^3, $P<0.001$) observed in this study is consistent with previous research demonstrating the positive effects of maxillary advancement on airway dimensions. It is important to note that the extent of maxillary advancement may be influenced by cleft type. UCLP patients often present with asymmetric maxillary retrusion and unilateral scar tissue, leading to differential bone remodeling compared to BCLP cases, where scarring is more symmetrically distributed. Studies by Mistry et al. (9) and Shokri et al. (13) have shown that maxillary distraction can improve airway patency by increasing the anteroposterior dimensions of the nasopharynx. This improvement is particularly important for patients with CLP, who often suffer from obstructive sleep apnea (OSA) due to midface retrusion and reduced nasopharyngeal space. The increase in nasopharyngeal volume observed in this study suggests that anterior maxillary distraction can effectively address airway obstruction, potentially reducing the severity of OSA and improving overall respiratory function.

In contrast, the oropharyngeal volume showed only a minimal increase (mean difference: 0.48 cm^3, $P=0.417$), which was not statistically significant. This finding is consistent with studies by Zhao et al. (15) and Shujaat et al. (16), which reported that maxillary advancement primarily affects the nasopharynx, with limited impact on the oropharynx. The oropharynx is influenced more by mandibular position and hyoid bone placement, which were not directly addressed in this study. Therefore, the lack of significant change in oropharyngeal volume is expected and highlights the need for a comprehensive approach to airway management in patients with CLP, particularly those with concurrent mandibular abnormalities.

The total pharyngeal volume also showed a significant increase (mean difference: 2.67 cm^3, $P<0.001$), further supporting the overall improvement in airway dimensions. This finding is consistent with studies by Chang et al. (17) and Celikoglu et al. (18), which reported similar increases in total pharyngeal volume following maxillary distraction. The improvement in total pharyngeal volume is due to the combined effects of nasopharyngeal expansion and the anterior movement of the maxilla, which creates more space in the upper airway.

The significant increases in maxillary sinus volumes (right: 2.53 cm^3, left: 2.73 cm^3, $P<0.001$) observed in this study are also noteworthy. The maxillary sinuses are strongly associated with the maxillary bone, and their volumes are influenced by the position and size of the maxillary bone. The increase in sinus volume following anterior maxillary distraction is consistent with studies by Yasin et al. (19) and Choi et al. (20), with similar findings. The expansion of the maxillary sinuses may contribute to improved sinus function, reduced sinusitis, and enhanced craniofacial balance. Additionally, the increase in sinus volume may be attributed to the forward movement of the maxilla, which creates more space in the sinus cavities.

Hard Tissue Changes

The significant improvement in the ANB angle (mean difference: 6.20°, $P<0.001$) observed in this study reflects the correction of the Cl III malocclusion commonly seen in patients with maxillary hypoplasia. The ANB angle is a key cephalometric parameter that assesses the sagittal

relationship between the maxilla and mandible. The increase in ANB angle indicates that the maxilla was advanced relative to the mandible, resulting in a more favorable skeletal relationship. This finding is consistent with studies by Figueroa et al. (21) and Ansari et al. (22), who reported similar improvements in ANB angle following maxillary distraction. The correction of the Cl III malocclusion is critical for achieving functional occlusion and improving facial aesthetics.

The increase in PNS-ANS distance (mean difference: 7.20 mm, P<0.001) reflects the anterior advancement of the maxilla, which is a key objective of the distraction procedure. The PNS-ANS distance is a measure of the extent of the maxillary base, and its increase indicates that the maxilla was successfully advanced. This finding is consistent with a study by Richardson (23), who reported similar increases in PNS-ANS distance following maxillary distraction. The anterior movement of the maxilla improves skeletal relationships and enhances facial proportions and aesthetics.

The significant changes in incisor positioning, including the increase in U1 to A-Pog angle (mean difference: 7.00°, P<0.001) and linear measurement (mean difference: 4.10 mm, P<0.001), indicate that the upper incisors became more proclined following the procedure. This change is consistent with studies by Chua et al. (24) and Wan et al. (25), who reported similar increases in incisor proclination following maxillary distraction. The proclination of the upper incisors may contribute to improved dental alignment and occlusion, enhanced lip support, and facial aesthetics.

The increase in U1 to NF distance (mean difference: 1.70 mm, P=0.001) and U1 to SN distance (mean difference: 3.80 mm, P=0.025) further supports the anterior movement of the maxilla and its associated dental changes. These findings are consistent with studies by Chow et al. (26) and Choi et al. (20), who reported similar increases in dental height and incisor positioning following maxillary distraction. The improvements in dental height and incisor positioning are critical for achieving functional occlusion and enhancing facial aesthetics.

The significant improvement in Wit's appraisal (mean difference: 4.90 mm, P<0.001) indicates a more favorable relationship between the maxilla and mandible. This finding is consistent with studies by Harada et al. (27) and Primrose et al. (28), who reported similar improvements in Wit's appraisal following maxillary distraction.

Soft Tissue Changes

The significant improvements in upper lip parameters, including upper lip length (mean difference: 3.30 mm, P<0.001), upper lip protrusion (mean difference: 3.00 mm, P<0.001), and upper lip position relative to the E-line (mean difference: 4.40 mm, P<0.001) and S-line (mean difference: 3.90 mm, P<0.001), highlight the aesthetic benefits of anterior maxillary distraction. These findings are consistent with studies by Chua et al. (24) and Wan et al. (25), which reported similar improvements in lip positioning and facial aesthetics following maxillary distraction. The increase in upper lip length and protrusion is particularly important for patients with CLP, who often have retruded upper lips due to maxillary hypoplasia. The improvement in lip positioning relative to the E-line and S-line reflects a more favorable facial profile, which is critical for enhancing the overall appearance and self-esteem of patients with CLP.

While anterior maxillary distraction significantly improves facial aesthetics and airway function, individual variations in treatment response must be considered. Cleft type is an important factor in determining treatment outcomes. UCLP patients may benefit from additional stabilization techniques or asymmetric force application to counteract unilateral soft tissue tension. BCLP cases, on the other hand, may require greater focus on maintaining skeletal stability due to the extent of midface deficiency. Future research should refine treatment protocols to optimize distraction forces based on cleft type.

The extent of scarring and soft tissue tension in UCLP cases may contribute to uneven maxillary advancement and require customized force application to ensure balanced skeletal movement. In contrast, BCLP patients, due to the symmetrical distribution of scarring, may experience more uniform distraction but could be at a higher risk of relapse due to greater midface deficiency. This consideration underscores the importance of tailored treatment planning to maximize stability and functional outcomes in CLP patients. Understanding the biomechanical differences between UCLP and BCLP cases will allow for improved clinical strategies that minimize relapse and enhance long-term skeletal positioning.

Further studies should focus on long-term follow-up to assess skeletal stability and airway improvements in different cleft types, ensuring that distraction protocols are optimized for each patient's unique anatomical and functional needs.

Conclusion

In conclusion, anterior maxillary distraction using a tooth-borne modified Hyrax appliance is a highly effective treatment for maxillary hypoplasia in patients with cleft lip and palate (CLP), offering significant functional and aesthetic benefits. The procedure improves nasopharyngeal and total pharyngeal volumes, enhancing airway patency and addressing obstructive sleep apnea. Hard tissue advancements, such as increased ANB angle and PNS-ANS distance, correct skeletal discrepancies, while soft tissue changes, including upper lip length and protrusion, enhance facial aesthetics. Overall, this technique provides a comprehensive solution for improving both function and appearance in CLP patients, underscoring its clinical significance. Continued research and technological advancements will further optimize its application, ensuring better outcomes for patients with maxillary hypoplasia.

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Conflict of Interests

The authors declare that they have no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available upon request.

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