

Morphometric Evaluation of Pterygomaxillary Region using Cone Beam Computed Tomography

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Received 2024-01-03; Accepted 2024-01-24; Online Published 2024-09-01

Abstract

Introduction: This study aimed to evaluate the anatomy of the pterygomaxillary region and the position of the descending palatine artery using CBCT sections.

Methods: In this analytical cross-sectional study, an evaluation of CBCT scans from 280 patients was undertaken. Axial sections of these images were utilized to determine the thickness, width, and location of the descending palatine artery, as well as the length of the pterygoid plates within the pterygomaxillary region. Convenient sampling was employed to gather these CBCT scans.

Results: The mean anterior length was higher in men (41.1 ± 5.6 vs. 39.8 ± 6.2) (both with $P < 0.05$). The mean length of lateral plate was 12.07 ± 2.2 and 11.1 ± 2.5 mm in men and women, respectively on the right side ($P = 0.001$) and it is significantly higher in men (12.5 ± 4.7 vs. 11.1 ± 2.5) on the left side ($P = 0.002$). The mean length of the medial plate in men and women was nearly similar and significant on the left side ($P = 0.005$). The thickness of the trigomaxillary region and the pterygoid appendage were not significantly different in men and women and both sides. It has been determined that the distance between the descending palatine canal and the piriform rim is longer in females on both sides.

Conclusion: The intricate morphology of the pterygomaxillary region can harbor anatomical variations that increase the risk of specific complications during Le Fort I osteotomy. To mitigate these potential risks, pre-operative imaging with CBCT is crucial for scrutinizing the pterygomaxillary region.

Keywords: Morphometry, Cone-Beam CT, LeFort Osteotomy, Pterygomaxillary fissure.

Citation: Ghaznavi A, Ilkhani S, Amirzahiri M, Ghoharfar Z. A case of borderline leprosy revealed by immunosuppressive treatment for systemic lupus erythematosus. Int J Travel Med Glob Health, 2024;12(3):174-179. doi: 10.30491/ijtmgh.2024.433831.1399.

Introduction

Le Fort I osteotomy, a time-honored and dependable surgical technique, stands as a widely employed method for rectifying maxillofacial anomalies¹. Pioneered by von Langenbach in 1859 for addressing nasopharyngeal polyps², Le Fort I surgery has evolved into a mainstay treatment option, lauded for its technical straightforwardness, its applicability in addressing a multitude of aesthetic and functional deformities, and its relatively low complication rate³. While generally considered a safe procedure, a substantial body of literature has documented a range of complications associated with Le Fort I osteotomy^{3, 4}. Among these, pterygomaxillary separation (PMS) bears significant responsibility for the more severe complications arising from this procedure⁴.

The trigomaxillary junction, one of the sutures disrupted during Le Fort I surgery⁵, is a complex three-dimensional structure that articulates the maxilla and the pterygoid plates of the sphenoid bone⁶. Its morphology can be characterized by the thickness, height, and angle formed by the bone union relative to the mid-sagittal plane of the skull⁶. The lower portion of this region originates at the juncture between the maxilla's tuberosity and the pterygoid plate, while its upper portion constitutes the base of the pterygoid fissure and behind this intricate area lies the pterygoid network, with its inner aspect abutting the larger palatine foramen⁷. Due to the complexity of the trigomaxillary junction and the difficulty in directly visualizing it during Le Fort I maxillary osteotomy, obtaining comprehensive

information about its morphology is of paramount importance ⁸.

Cone beam computed tomography (CBCT), a widely employed imaging modality in the maxillofacial region, offers the unique advantage of visualizing anatomical structures in three orthogonal planes: coronal, sagittal, and axial ⁹. This three-dimensional representation effectively eliminates the potential for anatomical landmarks to overlap, minimizing observation errors and enhancing the accuracy of diagnosis and treatment planning ^{10, 11}. The intricate anatomy of the trigomaxillary region, which encompasses a multitude of anatomical landmarks, necessitates the utilization of 3D imaging tools over conventional 2D methods to prevent the superposition of these structures and ensure precise assessment ¹². Furthermore, given its lower radiation exposure compared to conventional computed tomography (CT), CBCT emerges as an optimal imaging modality for evaluating the trigomaxillary region ¹³.

To safeguard the maxillary artery during pterygomaxillary separation, a crucial step in Le Fort I osteotomy, thorough knowledge of the morphometric features of the PMJ is essential. These features, including its thickness, width, and height, play a pivotal role in determining the surgical approach and minimizing the risk of vascular injury ¹⁴. This study aimed to evaluate the anatomy of the pterygomaxillary region and the position of the descending palatine artery using CBCT sections.

Methods

Ethical approval for this study was granted by the Research Ethics Committee of Urmia University Sciences (approval number: IR.UMSU.REC.1401.084). In this analytical cross sectional study, complying with the study's criteria, a retrospective evaluation of CBCT images from 280 patients was conducted, assessing the thickness and width of the pterygomaxillary region, the location of the descending palatine artery, and the length of the pterygoid plates on axial sections. These CBCT images were conveniently selected from January 2022 to December 2022 at Urmia University's Faculty of Dentistry, Oral and Maxillofacial Radiology Department. The inclusion criteria were high-quality and clear CBCT images, CBCT images of individuals between the ages of 18 and 75 years, and images with adequate visualization of the bilateral trigomaxillary region. Exclusion criteria were images with incomplete coverage of the target area, the presence of defects or pathology in the posterior region, previous tumor or cyst surgery, trauma or orthognathic surgery history, artifacts affecting image quality.

Examination of the CBCT Images

The CBCT images analyzed in this study were obtained using Planmeca Promax 3D Did (Planmeca, Helsinki, Finland) devices. These images provided comprehensive visualization of the maxilla and the pterygoid process of the sphenoid bone in the axial sections. The field of view (FOV) adapted to individual patient requirements, ranging from 15 to 16 cm. The scanning parameters were set at 90 kVp, 12 mA, and a scan time of 13.85 seconds. The images were composed of 0.4 x 0.4 x 0.4 mm voxels. The image evaluation was conducted using the R program in conjunction with the medical computer Planmeca Romexis 2.7.0., equipped with an NVIDIA QUADRO FX380 graphics card of 24-inch size and 720 x 1080 pixels resolution. This task was undertaken by an Oral and Maxillofacial Surgeon. Subsequently, 10% of the images were reevaluated by an Oral and Maxillofacial radiologist, and the observer variation was statistically assessed.

Measurements Performed on the CBCT Images

Coronal views, which provide a comprehensive depiction of the nasal bone, served as reference images for generating secondary reconstructions. On these coronal images, a sagittal guideline was positioned along the midline of the anterior nasal spine. This guideline was used to reconstruct a secondary sagittal image. The sagittal image was then obtained from the reference coronal image. Next, guiding points were marked on axial images at specific locations: Point A, 2 mm superior to the approximate center of the nasal floor; and Point B, 5.2 mm superior to the approximate center of the nasal floor. Axial slices were obtained between these points, and the axial slice with the clearest visualization of the pterygomaxillary region was selected for measurements. Target distances were measured according to standardized definitions established based on the findings and methods of previous studies ^{1, 15}.

1. Anterior Length (Ant Length): The distance between the pyriform rim and the most anterior point of the descending palatine canal.
2. Lateral Plate Length (LP Length): The shortest distance between the most posterior point of the lateral pterygoid plate and the most concave point of the pterygomaxillary fissure (Figure 1, part B).
3. Medial Plate Length (MP Length): The distance between the most posterior point of the medial pterygoid plate and the most medial point of the pterygomaxillary fissure line (this line passes through parallel to the coronal guide line passing through the most concave point of the pterygomaxillary junction.) (Figure 1, part C).



Figure 1. Axial view of the pterygomaxillary region in CBCT imaging by measuring the anterior plate of the pterygoid area (A), the lateral plate of the pterygoid (B) and the medial plate of the pterygoid

4. The thickness of the pterygoid process (Thickness of PP): The distance between the pterygomaxillary fissure line and the deepest point of the pterygoid fossa (Figure 2, part B)

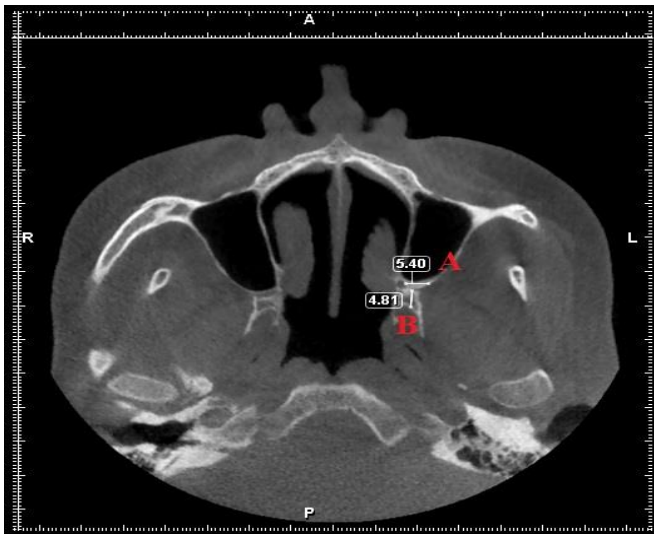


Figure 2. Axial view of the pterygomaxillary region in CBCT imaging by measuring the distance between the trigomaxillary groove and the palatine canal (A) and measuring the thickness of the pterygoid appendages (B).

5. The thickness of the pterygomaxillary region (Thickness of PMR): The shortest distance between the deepest point of the pterygoid fossa and the posterior wall of the maxillary sinus (Figure 3).
6. The distance between the pterygomaxillary fissure and the descending palatine canal (PMF-DPC): The shortest distance between the most concave point of the pterygomaxillary fissure laterally and the descending palatine canal (Figure 3, part A).



Figure 3. Axial view of the pterygomaxillary region in CBCT imaging with the measurement of the thickness of the trigomaxillary region

Upon completing the measurements (recorded in millimeters), the collected data, accompanied by relevant demographic information (gender) and the studied side (right/left), was encoded and entered into SPSS version 27 software for statistical analysis in accordance with the study's objectives.

Sample size

The minimum sample size using the results of Odabasi et al.'s study ¹⁶, considering the significance level of 95%, the standard deviation of 2.75 for the anterior length of the left trigomaxillary groove, and also considering the standard error of 0.01, as well as the following formula, finally, 280 cases were calculated. The computing power is considered to be 80%.

$$n = \frac{z_{1-\frac{\alpha}{2}}^2 \sigma^2}{d^2}$$

Statistical analysis

The results of the study have been reported using descriptive statistics such as mean $\pm$ standard deviation and frequency (percentage). The independent t-test was used to compare the measured values among gender groups, and the paired t-test was used to compare the measured values in the two sides of the study. The significance level in this study was $P < 0.05$ and statistical analysis was performed using SPSS version 27 software.

Results

In this study, 310 CBCT images were initially evaluated, of which 280 cases (140 women, 140 men) were subjected to final analysis after considering the inclusion and exclusion criteria.

On the right side, the mean Ant length was 41.9 ± 3.3 and 40.6 ± 2.6 mm in men and women, respectively. This difference was statistically significant ($P = 0.001$). The mean anterior length in male (41.1 ± 5.6) is significantly higher than that of women (39.8 ± 6.2) in the left side which is significant ($P=0.028$).

The mean LP length on the right and left sides was 11.6 ± 2.3 and 11.8 ± 3.8 mm, respectively, that there was not statistically significant difference between the two sides ($p=0.256$). The mean length of the LP was 12.07 ± 2.2 and 11.1 ± 2.5 mm in men and women, respectively, this difference was significant ($P=0.001$). Also, in the left side, the mean LP is significantly higher in men (12.5 ± 4.7) than in women (11.1 ± 2.5) which is statistically significant ($P=0.002$).

The mean MP length on the right and left sides was 7.6 ± 1.9 and 7.9 ± 2.6 mm, respectively, which was statistically significant ($P= 0.001$). The mean length of the MP was higher in women (8.1 ± 2.2) than in men (7.7 ± 2.9) on the left side, but it is not significant ($P = 0.168$). Regarding the opposite side, the mean length of the MP in men and women was nearly similar (7.3 ± 2.03 vs. 7.9 ± 1.7). This difference was significant ($P=0.005$).

The mean PP thickness on the right and left side was 7.6 ± 1.9 and 7.9 ± 2.6 mm, respectively, and this difference was not statistically significant ($P=0.120$). On the left side, the mean PP thickness in men and women was 7.7 ± 1.6 and 7.3 ± 1.7 mm ($P=0.068$). On the right side, the mean PR thickness in men (7.7 ± 1.5) and women (7.6 ± 1.4) did not have a significant difference ($p=0.409$).

The mean thickness of PMR on the right and left sides was 3.4 ± 0.8 and 3.8 ± 2.6 mm, respectively ($P=0.062$). On the left side, the mean PMR thickness in men and women was 4.03 ± 1.6 and 3.6 ± 1.7 mm, respectively ($p=0.172$). On the right side, the mean thickness of PMR region in men (3.3 ± 0.8) and women (3.5 ± 0.7) did not have a significant difference ($076 /0P=$).

The mean PMR-DPC on the right and left sides was 5.7 ± 1.2 and 5.5 ± 1.1 mm, respectively ($P=0.092$). The mean PMR-DPC, in men and women was 5.4 ± 1.05 and 5.5 ± 1.2 mm, respectively, on the left side ($P 0.575 =$). The mean PMR-DPC on the opposite side, in men (5.6 ± 0.8) and women (5.8 ± 0.6) did not have significant difference ($P=0.249$) (Table 1).

Table 1. The statistical analysis of the measurements according to the gender and sides

Measurnment	Side	Gender	N	Mean $\pm$ SD	P-value
Ant Length	Left	Male	140	41.1 $\pm$ 5.6	0.028**
		Female	140	39.8 $\pm$ 6.2	
		Total	280	40.4 $\pm$ 6.4	0.068*
	Right	Male	140	41.9 $\pm$ 3.3	0.001**
		Female	140	40.6 $\pm$ 2.6	
		Total	280	41.3 $\pm$ 3.08	0.068*
LP Length	Left	Male	140	12.5 $\pm$ 4.7	0.002**
		Female	140	11.5 $\pm$ 2.5	
		Total	280	11 $\pm$ 38	0.256*
	Right	Male	140	12.07 $\pm$ 2.2	0.001**
		Female	140	11.1 $\pm$ 2.5	
		Total	280	11.6 $\pm$ 23	0.256*
MP Length	Left	Male	140	7.7 $\pm$ 2.9	0.168**
		Female	140	8.1 $\pm$ 2.2	
		Total	280	7.9 $\pm$ 2.6	0.001*
	Right	Male	140	7.9 $\pm$ 1.7	0.005**
		Female	140	7.7 $\pm$ 2.9	
		Total	280	7.6 $\pm$ 1.9	0.001*
Thickness of PP	Left	Male	140	7.7 $\pm$ 1.6	0.068**
		Female	140	7.3 $\pm$ 1.7	
		Total	280	7.9 $\pm$ 2.6	0.120*
	Right	Male	140	7.7 $\pm$ 1.5	0.409**
		Female	140	7.6 $\pm$ 1.4	
		Total	280	7.6 $\pm$ 1.9	0.120*
Thickness of PMR	Left	Male	140	4.03 $\pm$ 1.6	0.06**
		Female	140	3.6 $\pm$ 1.7	
		Total	280	3.8 $\pm$ 2.6	0.062*
	Right	Male	140	3.3 $\pm$ 0.8	0.172**
		Female	140	3.5 $\pm$ 0.7	
		Total	280	3.4 $\pm$ 0.8	0.062*
PMR-DPC	Left	Male	140	5.4 $\pm$ 1.05	0.575**
		Female	140	5.5 $\pm$ 1.2	
		Total	280	5.5 $\pm$ 1.1	0.092*
	Right	Male	140	5.6 $\pm$ 0.8	0.249**
		Female	140	5.8 $\pm$ 0.6	
		Total	280	5.7 $\pm$ 1.2	0.092*

Paired-T test*, Independent-T test*

Discussion

During the Lefort I osteotomy procedure, if the lateral nasal osteotomy is excessively advanced posteriorly, there is a risk of damaging the descending palatine artery, which lies within the lateral nasal wall ¹⁷. Consequently, accurate knowledge of the distance between the pyriform rim and the descending palatine artery, also known as the anterior plate distance, is crucial to minimize the likelihood of complications involving this artery ^{18,8}.

Our study determined that the mean Ant length of the pterygomaxillary plates was 40.4 mm on the left side and 41.3 mm on the right side. A significant difference was observed between right mean Ant lengths in men and women, with men having a mean length of 41.9 mm and women having a mean length of 40.6 mm. Left mean Ant length in male (41.1 mm) is significantly higher than that of women (39.8 mm) which is significant ($P=0.028$). This finding is consistent with previous studies, which have reported mean Ant lengths in the range of 38 to 40 mm ^{15,16}. In another similar study conducted by Kim et al. on cadaver samples, the Anth length of the plate in men (38.4 mm) was significantly higher than that in women (34.6 mm) ². While the existing variations in facial and skull morphology can be attributed to factors such as race and nationality. Notable differences between the left and right sides of the pterygomaxillary plates have not been consistently reported in previous studies, but is consistent with our findings. However, our study corroborates previous studies by demonstrating that the Ant plate distance in men is significantly greater than in women, emphasizing the importance of meticulous surgical technique during osteotomies in women to safeguard the descending palatine artery.

The present study revealed that the lateral and medial pterygoid plate distances ranged from 10 to 12 mm and 7 to 9 mm, respectively. Similar to the anterior distance, no significant difference was observed between the lateral distances on the left and right sides, and the lateral distance in men was consistently greater than in women. Conversely, the medial pterygoid plate distance was significantly greater in women compared to men. This finding aligns with the results of a previous study ¹⁶, which reported an overall mean lateral distance of approximately 12 mm on both sides without significant inter-group differences. However, in contrast to our study, no significant gender-based differences were observed in the lateral distance in that study. The medial distance in the previous study also concurred with our findings, indicating a mean distance of approximately 7.5 mm, and a higher distance in women compared to men. Some researchers have proposed that unknown muscular movements in women might contribute to the increased medial pterygoid plate distance, a hypothesis supported

by the findings of Lee et al., which also demonstrated a significant gender disparity in the medial distance ¹⁹.

The present study determined that the mean thickness of the pterygomaxillary plates was 3 to 4 mm, with no significant differences observed between the left and right sides or between men and women. Previous research ¹⁴ reported a mean pterygomaxillary region thickness of 1.9 ± 1.2 mm in patients older than 30 years of age and 2.8 ± 1.9 mm in patients younger than 30 years old. This difference was statistically significant, indicating a decrease in PMR thickness with increasing age. In the present study, pterygomaxillary zone thickness less than 2.6 mm was identified as a risk factor for lateral and medial plate fractures during pterygomaxillary separation procedures performed without the use of osteotomes.

The mean PP thickness was 7.6 mm on the right side and 7.9 mm on the left side, with no statistically significant difference between the two sides ($P = 0.120$). It was also found to be similar in men and women on both sides. This finding contrasts with a previous study by Romoozi et al., which reported a thicker PP in women and negative values in 5.5% of cases ²⁰. Additionally, according to a study reports ²¹, a significantly higher mean Ant length between the descending palatine canal and the lateral wall of the piriform rim in men compared to women ($P = 0.012$). Contrary to this finding, our study demonstrated no significant difference in anterior length between the two sexes.

Conclusion

The findings of this study clearly demonstrated a significant degree of variation in the morphometric coordinates of the pterygomaxillary region. This anatomical variability can influence the efficacy of anesthesia or maxillary nerve blocks in patients with trigeminal neuralgia. Therefore, having accurate knowledge of the pterygomaxillary region's anatomy prior to any procedure is particularly valuable for clinicians performing guided nerve blocks using CBCT or CT guidance. Consequently, CT imaging of the pterygomaxillary region is recommended prior to Le Fort I osteotomy, and preoperative measures should be implemented to address potential complications.

Highlights

What is already known?

Le Fort I osteotomy stands as a widely employed method for rectifying maxillofacial anomalies. The trigomaxillary junction, one of the sutures disrupted during Le Fort I surgery is a complex three-dimensional structure that articulates the maxilla and the pterygoid plates of the sphenoid bone.

What Does This Study Add?

A significant degree of variation exists in the morphometric coordinates of the pterygomaxillary region. This anatomical variability can influence the efficacy of anesthesia or maxillary nerve blocks in patients with trigeminal neuralgia.

Acknowledgments

The authors would like to express their gratitude to the clinical research development unit of Imam Khomeini Hospital, Urmia University of Medical Sciences, for English editing.

Funding support

The authors did not receive support from any organization for the submitted work

Competing interests

The authors have no competing interests to declare that are relevant to the content of this article.

Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Urmia University of Medical sciences (No. IR.UMSU.REC.1401.084).

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Author contributions

Aisan Ggaznavi: Conceptualization, the original draft writing, investigation, writing including reviewing and editing and investigation and formal analysis; Sina Ilkhani: Conceptualization, supervision, and project administration; Maryam Amirzahari: Investigation, writing including reviewing and editing; Zahra Ghoharfar: Conceptualization, supervision, and project administration

References

- Breeze J, Linares CV, Stockton P. Is an osteotome necessary for pterygomaxillary dysjunction or dysjunction through the tuberosity during Le Fort I osteotomy? A systematic review. *British Journal of Oral and Maxillofacial Surgery*. 2016;54(3):248-52. [doi: 10.1016/j.bjoms.2015.11.014](https://doi.org/10.1016/j.bjoms.2015.11.014).
- Kim DY CY, Sung IY, Yun DK, Kim MU, Kim JU, Son HS, Son JH. . Anatomic study of pterygomaxillary junctions in Koreans. . *Maxillofacial Plastic and Reconstructive Surgery*. 2013;35(6):368-75. [doi:10.14402/jkamprs.2013.35.6.368](https://doi.org/10.14402/jkamprs.2013.35.6.368)
- Garg S, Kaur S. Evaluation of post-operative complication rate of Le Fort I osteotomy: a retrospective and prospective study. *Journal of maxillofacial and oral surgery*. 2014;13:120-7. [doi: 10.1007/s12663-012-0457-4](https://doi.org/10.1007/s12663-012-0457-4).
- Bilge S, Kaba YN, Demirbas AE, Kütük N, Kiliç E, Alkan A. Evaluation of the pterygomaxillary separation pattern in Le Fort I osteotomy using different cutting instruments. *Journal of Oral and Maxillofacial Surgery*. 2020;78(10):1820-31. [doi: 10.1016/j.joms.2020.06.003](https://doi.org/10.1016/j.joms.2020.06.003).
- Joshi RJ, AlOtaibi N, Naudi K, Henderson N, Benington P, Ayoub A. Pattern of pterygomaxillary disarticulation associated with Le Fort I maxillary osteotomy. *British Journal of Oral and Maxillofacial Surgery*. 2022;60(10):1411-6. [doi: 10.1016/j.bjoms.2022.08.003](https://doi.org/10.1016/j.bjoms.2022.08.003).
- Tunis TS, Dratler S, Kats L, Allon DM. Characterization of Pterygomaxillary Suture Morphology: A CBCT Study. *Applied Sciences*. 2023;13(6):3825. [doi:10.3390/app13063825](https://doi.org/10.3390/app13063825)
- Chin Y-P, Leno MB, Dumrongwongsiri S, Chung KH, Lin H-H, Lo L-J. The pterygomaxillary junction: An imaging study for surgical information of LeFort I osteotomy. *Scientific reports*. 2017;7(1):9953. [doi: 10.1038/s41598-017-10592-8](https://doi.org/10.1038/s41598-017-10592-8).
- Dabir A, Vahanwala J. Orthognathic surgery for the maxilla-LeFort I and anterior maxillary osteotomy. *Oral and Maxillofacial Surgery for the Clinician*. 2021;1513-48. [doi:10.1007/978-981-15-1346-6_69](https://doi.org/10.1007/978-981-15-1346-6_69)
- Venkatesh E ES. Cone beam computed tomography: basics and applications in dentistry. *J Istanbul Univ Fac Dent* 2017;Dec 2(51(3 Suppl 1)):S102-S21. [doi: 10.17096/jiufd.00289](https://doi.org/10.17096/jiufd.00289).
- Patel S, Brown J, Pimentel T, Kelly R, Abella F, Durack C. Cone beam computed tomography in Endodontics—a review of the literature. *International endodontic journal*. 2019;52(8):1138-52. [doi: 10.1111/iej.13115](https://doi.org/10.1111/iej.13115).
- Gkantidis N, Schauseil M, Pazera P, Zorkun B, Katsaros C, Ludwig B. Evaluation of 3-dimensional superimposition techniques on various skeletal structures of the head using surface models. *PloS one*. 2015;10(2):e0118810. [doi: 10.1371/journal.pone.0118810](https://doi.org/10.1371/journal.pone.0118810)
- Chen W, Li Y, Tian Z, Zhang F. 2D and 3D object detection algorithms from images: A Survey. *Array*. 2023;100305. [doi:10.1016/j.array.2023.100305](https://doi.org/10.1016/j.array.2023.100305)
- Kemp P, Van Stralen J, De Graaf P, Berkhout E, Van Horsen P, Merkus P. Cone-beam CT compared to multi-slice CT for the diagnostic analysis of conductive hearing loss: a feasibility study. *The Journal of International Advanced Otolaryngology*. 2020;16(2):222. [doi: 10.5152/iao.2020.5883](https://doi.org/10.5152/iao.2020.5883).
- Kanazawa T, Kuroyanagi N, Miyachi H, Ochiai S, Kamiya N, Nagao T, et al. Factors predictive of pterygoid process fractures after pterygomaxillary separation without using an osteotome in Le Fort I osteotomy. *Oral surgery, oral medicine, oral pathology and oral radiology*. 2013;115(3):310-8. [doi: 10.1016/j.oooo.2012.04.020](https://doi.org/10.1016/j.oooo.2012.04.020).
- Ueki K, Miyazaki M, Okabe K, Mukozawa A, Marukawa K, Moroi A, et al. Assessment of bone healing after Le Fort I osteotomy with 3-dimensional computed tomography. *Journal of Cranio-Maxillofacial Surgery*. 2011;39(4):237-43. [doi: 10.1016/j.jcms.2010.06.008](https://doi.org/10.1016/j.jcms.2010.06.008).
- Odabaşı O EE, Üçok CÖ, Bakir MA, Keriş EY, Şahin O. Morphometric analysis of pterygomaxillary region by using cone beam computed tomography. *J Stomatol Oral and Maxillofac Surg*. 2021;122(3):273-7. [doi: 10.1016/j.jormas.2020.06.006](https://doi.org/10.1016/j.jormas.2020.06.006).
- Park B, Jang W-H, Lee B-K. An idiopathic delayed maxillary hemorrhage after orthognathic surgery with Le Fort I osteotomy: a case report. *Journal of the Korean Association of Oral and Maxillofacial Surgeons*. 2019;45(6):364-8. [doi: 10.5125/jkaoms.2019.45.6.364](https://doi.org/10.5125/jkaoms.2019.45.6.364).
- Wang Y-Y, Lin Y-Y, Qiao T, Duan J-H, Yang Y-Q, Hou M. Extended Maxillary Osteotomy Guide: A Design That Allows Manipulation of the Osteotomy Direction on the Posterior and Inner Walls of the Maxilla. *Journal of Craniofacial Surgery*. 2022;33(7):2146-53. [doi: 10.1097/SCS.00000000000008740](https://doi.org/10.1097/SCS.00000000000008740).
- Lee S-H, Lee S-H, Mori Y, Minami K, Park H-S, Kwon T-G. Evaluation of pterygomaxillary anatomy using computed tomography: are there any structural variations in cleft patients? *Journal of oral and maxillofacial surgery*. 2011;69(10):2644-9. [doi: 10.1016/j.joms.2011.01.004](https://doi.org/10.1016/j.joms.2011.01.004).
- Romoozi E, Razavi SH, Barouti P, Rahimi M. Investigating the morphologic indices of the hamulus pterygoid process using the CBCT technique. *J Res Med Dent Sci*. 2018;6(2):240-4. [doi: 10.5455/jrmds.20186237](https://doi.org/10.5455/jrmds.20186237)
- Oliveira G, Rossi M, Vasconcelos T, Neves F, Crusoé-Rebello I. Cone beam computed tomography assessment of the pterygomaxillary region and palatine canal for Le Fort I osteotomy. *International Journal of Oral and Maxillofacial Surgery*. 2017;46(8):1017-23. [doi: 10.1016/j.ijom.2017.03.030](https://doi.org/10.1016/j.ijom.2017.03.030).