EXPERIMENTAL STUDY

Radiological examination of the relationship between the pterygomaxillary junction and fracture pattern

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ABSTRACT

BACKGROUND: Le Fort I (LF1) osteotomies are widely used to correct midface deformities. To move the maxilla freely, the pterygomaxillary junction (PMJ) must be separated. When performing this osteotomy, the pterygoid plate must remain intact. The objective of this study was to evaluate relationship between the anatomical features of the PMJ and fracture patterns in LF1 osteotomy.

METHODS: Pre-operative and post-operative cone-beam computed tomography images of 41 patients (82 samples) who have undergone LF1 osteotomy surgery were radiologically evaluated. Morphologic measurements of the pterygomaxillary fissure area and pterygoid plate were carried out. Moreover, pterygomaxillary separation was divided into the clean-cut, maxillary sinus, and pterygoid plate fracture types.

RESULTS: Statistically significant difference was observed between clean-type fracture and pterygoid plate fracture groups' thickness of the pterygoid process and thickness of the pterygomaxillary region.

CONCLUSION: Anatomical variations make it difficult to separate the PMJ properly. Low thickness of PMJ increases the risk of unwanted fractures; however, according to our experience, the use of an osteotome with an incorrect angle, excessive force, and inexperienced surgeons can also cause undesirable pterygoid plate fractures.

Keywords: Maxilla; orthognathic surgery; osteotomy; pterygoid plate; tomography.

INTRODUCTION

von Langenbeck described Le Fort I (LF1) osteotomy in 1859, and Wassmund applied it for the first time in 1927 to correct midface deformities.[1] Its name is derived from Rene LeFort's 1901 description of the LF1 horizontal fracture pattern.[2] Axhausen and Schuchardt, then, described the separation of the pterygomaxillary junction (PMJ) using an osteotome; this is a critical aspect of LF1 osteotomy that enables maxillary movement.[3] The optimum separation line begins lateral to the PMJ and runs medially through the pterygomaxillary fissure between the maxilla and the lateral pterygoid process of the sphenoid bone.[4]

Separation of the PMJ is a crucial step during LF1 osteotomy that allows the maxilla to move freely. However, this stage carries some risks and difficulties as it is performed only by hand manipulation and tactile sensations without direct visualization of the surgical area. Following a poor PMJ split, complications such as restricted mobility of the maxillary segment, pterygoid plate fracture, and vascular and neural injuries might occur. Due to these risks, anatomical structure of the region should be well known.[5]

When performing the pterygomaxillary osteotomy, the pterygoid plate must remain intact. In the literature, it is unclear whether different types of craniomaxillofacial defor-

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mities affect PMJ structure or intraoperative pterygoid plate fracture. Therefore, this study examines whether there is a relationship between the anatomical features of the PMJ and fracture patterns.

MATERIALS AND METHODS

This study was conducted in accordance with the principles of the Declaration of Helsinki (2008). Approval for this study was obtained from Istanbul University, Faculty of Dentistry, Clinical Research Ethics Committee (05 April 2022–2022/24). Each patient signed informed consent forms before their radiological examination. In this study, LF1 operations were performed between 2017 and 2020 in İstanbul University, Faculty of Dentistry, Oral and Maxillafacial Surgery Department and the patients' before/after cone-beam computed tomography (CBCT) images were assessed. Inclusion criteria for the study were having undergone LF1 surgery with a CBCT image captured before and after the surgical procedure. Exclusion criteria were the presence of pathology or pathological surgery history in the head and neck region, trauma history, systemic conditions, a genetic disorder affecting the head and neck region, artifacts affecting CBCT image quality, and a history of cleft lip and palate. No sex preference was exercised in the sample choice.

All LF1 osteotomies were performed by the same experienced surgical team using the method described by Bell in 1975.[6]

The images were obtained with Scanora® 3Dx CBCT device (Soredex, Tuusula, Finland) and analyzed with the OnDemand 3D™ software (Cybermed, CA, USA) on a Beacon HL2416SH Medical LCD Monitor by Shenyang Torch-Bigtide Digital Technology Co. (Shenzhen, China) monitor. The minimum field of view size in the images included in the study was 140×165 mm, and the maximum field of view size was 240×165 mm. According to the selected field of view size, voxel size takes ranged from 0.1 to 0.5 mm^3 and section thickness in the range of 0.1–0.3 mm. The usage parameters of the device were 60–90 kV, 4–10 mA, target angle of 15°, and focal spot of 0.5 mm. The capture time was 18–24 s, and the effective exposure time was 2.4–6 s. The image receptor is a flat panel system.

In the present study, after power calculation, 82 samples (right and left) were evaluated by an oral and maxillofacial radiologist from the CBCT images of 41 patients. The CBCT images were aligned parallel to the Frankfurt horizontal plane to standardize the head position (Fig. 1). In addition to Frankfurt horizontal plane, the inferior orbital margin, the frontozygomatic sutures, and the porion landmark were also determined as guide points. In the axial images, measurements were made on the section with the clearest image, 2–5 mm superior to the nasal floor, using previous studies as a guide.[7–9]

In evaluating morphometric features, measurements shown in Figure 2 were used, basing these on previous studies.[7–9]

1. Anterior length: The distance between the most anterior point of the descending palatine canal (DPC) and the most anterior point of the lateral wall of the piriform rim.
2. Medial plate length: The shortest distance between the most posterior point of the medial pterygoid plate and the pterygomaxillary fissure line.*
3. Lateral plate length: The shortest distance between the most posterior point of the lateral pterygoid plate and the pterygomaxillary fissure line.
4. The thickness of the pterygoid process (thickness of PP): The distance between the most concave point of the pterygoid fossa and the pterygomaxillary fissure line.

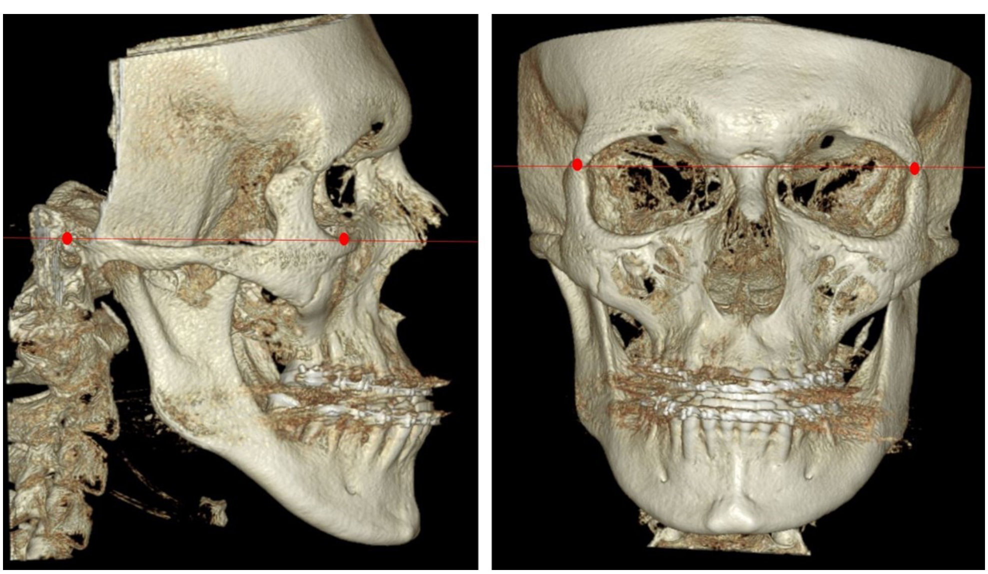

Figure 1. 3D reconstruction of the standardized head position.

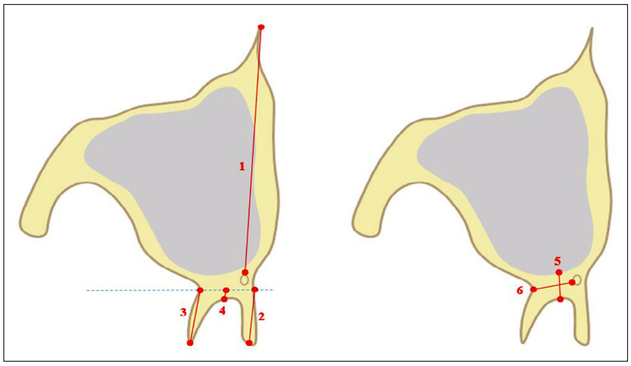

Figure 2. Morphometric features 1. anterior length, 2. medial plate length, 3. medial plate length, 4. the thickness of the pterygoid process (thickness of PP), 5. the thickness of the pterygomaxillary region (thickness of PMR), and 6. the distance between the pterygomaxillary fissure and the descending palatine canal (PMF-DPC).

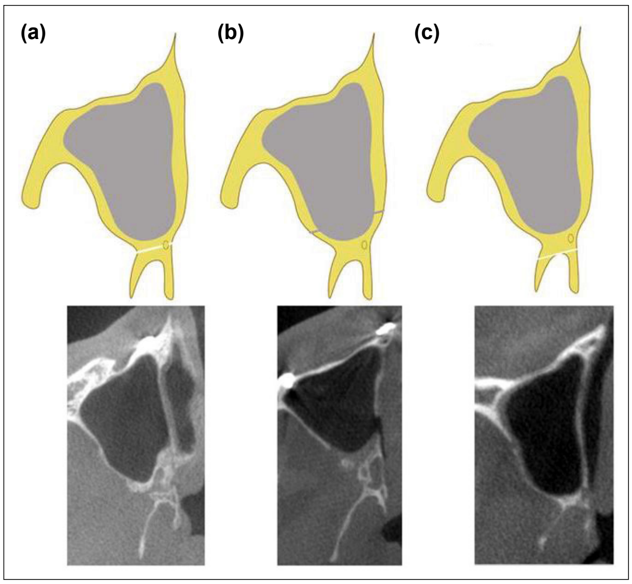

Figure 3. Pterygomaxillary separation types **(a)** clean cut type, **(b)** maxillary sinus type, and **(c)** pterygoid plate fracture type.

5. The thickness of the pterygomaxillary region (thickness of PMR): The distance between the most posterior portion of the maxillary sinus and the most concave point of the pterygoid fossa.
6. The distance between the pterygomaxillary fissure and the DPC (PMF-DPC): The distance between the most lateral point of the pterygomaxillary fissure and the DPC.

*The pterygomaxillary fissure line: Line passing through the most concave point of the PMJ.

Patients were subclassified according to the pterygomaxillary separation types demonstrated in Figure 3.

A. Clean cut type: This is the most desired cut type where the cut line is right within the PMJ.
B. Maxillary sinus type: This type is observed when the osteotomy is too anterior and the posterior wall of the maxillary sinus is in contact with the PMJ after the separation
C. Pterygoid plate fracture type: This type of separation occurs when the osteotomy is too posterior, leading to a pterygoid plate fracture.

Statistical analyses were performed with the Number Cruncher Statistical System (NCSS) 2007 Statistical Software (Utah, USA) package. In addition to descriptive statistical methods (mean, standard deviation, and min–max) in the evaluation of the data, the distribution of the data was examined with the Shapiro–Wilk's normality test. A one-way analysis of variance was used to compare normally distributed variables, while subgroups and paired groups were compared using Tukey's multiple comparison test. Independent t-test and Chi-square test were used for the comparison of qualitative data. Statistical significance was set at p<0.05.

RESULTS

No statistically significant difference was observed in age and sex distribution between Groups A, B, and C (p=0.141, p=0.291) (Table 1).

A statistically significant difference was observed between the fracture type A, B, and C groups' thickness of PP averages (p=0.013). The thickness of PP mean of group C was lower than group A (p=0.01), and no statistically significant difference was observed between the other groups (p>0.05).

A statistically significant difference was observed between the fracture type A and C groups' thickness of PMR averages (p=0.046). The mean PMR thickness of the C group was lower than group A (p=0.043), and no statistically significant differences were observed between the other groups and Group B (p>0.05). No statistically significant differences were observed between the PMF-DPC averages for fracture type from the A, B and C groups (p=0.837) (Table 2).

DISCUSSION

Maxillary LF1 osteotomies address dentofacial abnormalities, trauma, and skull base and midface tumors. Separating the PMJ during osteotomy is difficult for most surgeons since it

Table 1. Age and gender distribution

	Fracture type			p
	A (n=33)	B (n=6)	C (n=2)	
Age	26.12±6.75	21.00±2.53	29.50±6.36	0.141*
Gender, n (%)				
Male	18 (54.55)	3 (50.00)	3 (100.00)	0.291+
Female	15 (45.45)	3 (50.00)	0 (0.00)	

*One-way analysis of variance. +Chi-square test.

Table 2. Fracture types

	Fracture type			p
	A (n=63)	B (n=16)	C (n=2)	
Side, n (%)				
Right	30 (47.62)	10 (62.50)	2 (40.00)	0.511+
Left	33 (52.38)	6 (37.50)	3 (60.00)	
Anterior length (mm)	37.11±3.88 (27.4–43.8)	37.49±3.18 (28.9–42.3)	39.00±0.61 (38.3–39.4)	0.662*
Lateral plate length (mm)	9.99±3.58 (2.4–19.8)	9.57±2.55 (5.9–16.3)	12.00±2.23 (9.6–14)	0.522*
Medial plate length (mm)	7.39±2.47 (2.7–14.5)	6.78±2.32 (3.2–11.3)	8.93±2.08 (7.1–11.2)	0.343*
Thickness of PP (mm)	1.70±0.72 (0.5–4.9)	1.56±0.64 (0.9–3.1)	0.74±0.22 (0.5–0.9)	0.013*
Thickness of PMR (mm)	4.75±2.59 (1.2–14.6)	4.14±1.63 (1.4–8.3)	2.04±0.47 (1.7–2.8)	0.046*
PMF-DPC (mm)	3.55±1.27 (1.1–7.3)	3.34±1.24 (2.1–7)	3.60±0.20 (3.4–3.8)	0.837*

*One-way analysis of variance. +Chi-square test. Mean±SD (min-max). PP: Pterygoid process; PMR: Pterygomaxillary region; PMF-DPC: Pterygomaxillary fissure and the descending palatine canal.

is positioned behind the maxilla and cannot be visualized directly.[10] Non-ideal separation of the PMJ makes it harder to mobilize the maxilla, because muscle adhesions persist in the unbroken region of the pterygoid plate linked to the tuber maxilla. If the pterygoid process is not correctly separated, it can damage neurovascular structures in the pterygopalatine fossa during maxillary repositioning and impair maxillary retraction.[11]

Various studies explore pterygomaxillary anatomy. Cheung et al.[12] found synostosis in 12% of 30 dry human skulls and measured 34 mm between the piriform rim of the medial sinus wall and the DPC at the LF1 incision.

Oliveira et al.[8] compared the palatine canal to the piriform rim in 75 individuals to find that those of men were much further apart than those women. In the same study, the medial plate length was 7.53 mm, the lateral plate length was 12.17 mm, the average pterygomaxillary thickness was 7.68 mm, and the distance between the pterygomaxillary fissure and the DPC was 5.07 mm. In a study by Chin et al.[4] on 283 patients, Angle class 1, 2, and 3 patients had a pterygomaxillary thickness of 5.1±1.4 mm, a width of 9.7±1.7 mm, and a sagittal plane angle of 102.0±4.0 at the nasal spine level. All groups had similar values. In this investigation, the mean anterior length was 37.29±3.6 mm; lateral plate length 10.00±3.3 mm; and medial plate length 7.39±2.45 mm, which is similar to Oliveira et al. In our study, the PP was 1.62±0.72 mm and PMR was 4.47±2.44 mm, lower than Oliveira but consistent with Chin et al. PMF-DPC distance was 3.51±1.22 mm. Statistically, Group A had a thicker PP and PMR than Group C. In other words, thicker PP and PMR may enable a more favorable fracture pattern of PMJ, although further work is required.

Wikkeling and Koppendraaier divided PMJ fractures into three categories: Ideal fracture between the maxillary tuberosity and the pterygoid plate; oblique fracture along the dorsal maxillary sinus; and horizontal or near-horizontal fracture of the upper pterygoid plate.[13,14] The Wikkeling and Koppendraaier classifications were utilized in the present study.

Renick and Symington studied post-operative CTs of 24 Obwegeser separations in 12 patients. Half of the osteotomies were ideal separations, 25% were high-level pterygoid plate fractures, and the rest were low-level.[15] Only four of 16 osteotomies preserved the pterygoid plate, according to Robinson and Hendy.[16] Joshi et al.,[17] in their 70 patients' CBCT study, reported that most of the separations were at the PMJ or anterior the PMJ with intact pterygoid plates. Hiranuma et al.[18] compared curved Obwegeser osteomes to swan neck osteotomes and found that improper location caused pterygoid plate fracture. Stajic found that extending the angle of the curved osteotome to 80° lowered pterygoid plate fracture risk from 75% to 42%.[19]

Despite the significant complication rates associated with Bell's standard pterygomaxillary separation,[1] researchers felt the need to examine various pterygoid junction separation procedures. Trimble developed his trademark technique. Using an osteotome at the distal end of the second molar in the tuber region 0.5–1 cm above, the crest prevents pterygoid plate fractures. Straight osteotomes should be utilized 45° from the sagittal axis. Curved osteotomes minimize the osteotome's angle to the midsagittal axis. Hence, the osteotome does not damage the connection between the bone's horizontal process and the maxillary palatal project.[20]

Dadwal et al.[21] analyzed 16 osteotomies in eight individuals to determine pterygoid plate fracture risk. Only three of 16 osteotomies resulted in pterygoid plate fractures. The analysis found that Trimble was safer. In all pterygoid plate fracture instances, the PMJ thickness was <3.6 mm, highlighting the relevance of pre-operative PMJ thickness. Our study found a negative correlation between PMJ thickness and pterygoid plate fracture, similar to Dadwal's. Dadwal's study used fewer patients than ours.

The LF1 incisions were made neatly without pterygoid osteotomy and then downfractured with finger pressure and spreaders. If the maxilla was resistant to separation, flat, and thick chisels were used to perform the downfracture. Precious et al.[22] introduced this approach in 1991. In this procedure, classical LF1 incisions are done without osteotomy. Instead, a vertical center of rotation is formed at the PMJ area by exerting vertical finger pressure on the front maxilla and widening the incision sites on both sides. Tessier forceps are used to separate the zygomaticomaxillary buttresses. Bell's pterygomaxillary osteotomy technique lowers difficulties, but it has certain downsides, such as an inability to generate a clean incision line and pterygoid plate fractures. Joshi et al.[17] suggest using a Smith spreader and Rowe's forceps to safely separation at the PMJ. Kanazawa et al. analyzed 100 incisions using this approach and found that cases where the PMJ is <2.6 mm, and the tube is >11.5 mm increase the risk of pterygoid plate fracture. Men are at greater risk than women. In cases where the maxillary tuberosity is long, and the PMJ thickness is poor, Kanazawa et al. advocate vertical osteotomy from the third molar or distal to the second molar. Five osteotomies with pterygoid plate fractures had a thinner PMJ than the ideal group. All three pterygoid fracture cases were men. Our study did not measure tuber maxilla length. Our results agree with Kanazawa et al.[23]

Lanigan tested cadaver pterygomaxillary separation procedures in 1993. According to that study, undesired pterygoid plate fractures can occur with all procedures, but the Trimble technique increases the optimal separation rate. Angle saw osteotomies had the best results. In research assessing LF1 osteotomy problems, complication rates are lower than Lanigan's. This may be because Lanigan's study used cadavers with a high average age.[24]

Hwang et al.[25] studied PMJ fractures in 30 cadavers and found 24 clean separations and six pterygoid plate fractures. The group with appropriate separation had a substantially thicker PMJ than the other group. Thin PMJs and other anatomical differences make separation difficult.

Studies assess the effects of LF1 osteotomy tools on PMJ fracture types. Juniper and Stajcic recommend a right-angled micro-oscillating saw for pterygoid plate fractures.[19,26] Piezo devices utilized in LF1 osteotomy were found to be superior to reciprocating saws or burs years later. Bilge et al.[27] studied the impact of ultrasonic bone scalpels, Piezo saws, and Lindeman burs on PMJ separation in 96 LF1 osteotomies on 48 patients. Fifty-eight of 96 pterygomaxillary separations were excellent. Ultrasonic bone scalpel has the best separating rate. No significant difference was identified between PMJ anatomical measures and existing fracture types.

Low PMJ thickness and improper osteotome angle increase the incidence of unplanned fractures, according to our clinical experience. Inexperienced surgeons and excessive force can also lead to pterygoid plate fractures. Sharp, thin osteotomes are needed to enable a smooth separation. Swan-neck or shark-fin osteotomes are effective. This study used curved Obwegeser osteotomes with satisfactory results.

We examined the caudal positioning of the pterygoid osteotome tip during osteotomy, the osteotome's angle with the sagittal axis being 100–110°, as mentioned by Chin et al.[4] We believe the proper technique and angulation during osteotomy led to comparatively few pterygoid plate fractures. In our investigation, we used a traditional osteotomy procedure with a curved Obwegeser osteotome and other techniques not compared. Our study has this limitation. Despite this, the PMJ separation results utilizing the traditional approach and instruments were excellent. Pre-operative radiological evaluation is necessary to reduce LF1 osteotomy problems. Thin PMJs may be treated with the Trimble approach to avoid pterygoid plate fractures.

Conclusion

PMJ separation is a critical step during LF1 osteotomy for maxillary movement. While doing this osteotomy, the pterygoid plate must remain intact. It is uncertain if different forms of craniomaxillofacial defects impact PMJ structure or intraoperative pterygoid plate fractures. This study revealed a negative correlation between PMJ thickness and pterygoid plate fracture. Furthermore, using the proper method and angulation during the osteotomy, using a suitable amount of force, and experienced surgeons can result in fewer pterygoid plate fractures.

Ethics Committee Approval: This study was approved by the İstanbul University Faculty of Dentistry, Clinical Research Ethics Committee (Date: 05.04.2022, Decision No: 121).

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DENEYSEL ÇALIŞMA - *ÖZ*

Pterygomaksiller bağlantı ile kırık paterni arasındaki ilişkinin radyolojik incelenmesi

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AMAÇ: Le Fort I osteotomileri, orta yüz deformitelerini düzeltmek için yaygın olarak kullanılmaktadır. Maksillanın kolayca hareket etmesi için pterigomaksiller bileşke ayrılmalıdır. Bu osteotomiyi gerçekleştirirken pterigoid plak sağlam kalmalıdır. Bu çalışmanın amacı, Le Fort I osteotomisinde pterigomaksiller bileşkenin anatomik özellikleri ile kırık paternleri arasındaki ilişkiyi değerlendirmektir.
GEREÇ VE YÖNTEM: Le Fort I osteotomi ameliyatı geçirmiş 41 hastanın (82 örnek) ameliyat öncesi ve ameliyat sonrası konik ışınlı bilgisayarlı tomografi görüntüleri radyolojik olarak değerlendirildi. Pterigomaksiller fissür ve pterigoid plağın morfolojik ölçümleri yapıldı. Pterigomaksiller ayrılma, temiz kesim, maksiller sinüs ve pterigoid plak kırığı şeklinde ayrıldı.
BULGULAR: Temiz kesim tip kırık ve pterigoid plak kırığı gruplarının pterigoid proses kalınlıkları ile pterigomaksiller bölge kalınlıkları arasında istatistiksel olarak anlamlı fark gözlendi.
TARTIŞMA: Anatomik varyasyonlar pterigomaksiller bileşkenin düzgün ayrılmasını zorlaştırmaktadır. Pterigomaksiller bileşke kalınlığının az olması istenmeyen kırık riskini artırır; ancak tecrübelerimize göre yanlış açı, aşırı kuvvet ve deneyimsiz cerrahlar ile osteotom kullanımı da istenmeyen pterygoid plak kırıklarına neden olabilmektedir.
Anahtar sözcükler: Maksilla; ortognatik cerrahi; osteotomi; pterigoid plak; tomografi.

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