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ORIGINAL ARTICLE
ORİJİNAL ARAŞTIRMA

Morphological Analysis of Foramen Ovale and Foramen Lacerum in terms of Percutaneous and Endoscopic Endonasal Approaches

Foramen Ovale ve Foramen Lacerum'un Perkutanöz ve Endoskopik Endonasal Yaklaşımlar açısından Morfolojik Analizi

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ABSTRACT

Aim: It is clinically extremely important to determine the surrounding structures and variations of the foramen ovale, the region where mandibular nerve blockade is performed during percutaneous and endoscopic endonasal procedures. Therefore, this study was conducted to guide clinicians in determining and choosing the surgical method to be applied, especially percutaneous and endoscopic endonasal approaches, by investigating the relationship between foramen ovale, foramen lacerum and pterygoid processes on morphological basis.

Material and Method: The study was conducted with 56 skulls (right and left, 112 in total). In the lower view of the skull base, the horizontal relationship between the foramen ovale/foramen lacerum and the posterior border of the base of the lateral pterygoid processes was taken into account. Skulls with injuries to the lateral plate of the pterygoid process or foramen ovale and foramen lacerum on both sides were excluded.

Results: When the position of the foramen ovale relative to the processus pterygoideus lateralis was evaluated; the most common type II (medial type) was on the right with a rate of 30.3%, and type III (direct type) was on the left with a rate of 23.3%. The lowest rate was type IV. The foramen lacerum was in direct relationship with the medial pterygoid process posteromedially at a rate of 50%.

Conclusion: The fact that the foramen ovale is far from the foramen lacerum and pterygoid processes may make surgical procedures risky, as it will make it difficult to detect the origin of the mandibular nerve.

Keywords: Foramen ovale, Percutaneous approach, Foramen lacerum

ÖZ

Amaç: Perkutanöz ve endoskopik endonasal prosedürler sırasında mandibular sinir blokajının yapıldığı bölge olan foramen ovale'nin, çevre yapıları ve varyasyonlarını belirlemek klinik olarak son derece önemlidir. Dolayısı ile bu çalışma, foramen ovale, foramen lacerum ve processus pterygoideus'lar arasındaki ilişkiyi morofolojik temeller üzerinde araştırarak, perkutanöz ve endoskopik endonasal yaklaşımlar başta olmak üzere uygulanacak cerrahi yöntemin belirlenmesi ve tercih edilmesinde klinisyenlere yardımcı olmak amacı ile yapılmıştır.

Gereç ve Yöntem: Araştırma, 56 kafatası (sağ sol toplam 112) ile yapılmıştır. Kafa tabanının alttan görünümünde foramen ovale ve formaen lacerum ile processus pterygoideus lateralisin tabanının arka sınırı arasındaki yatay ilişki dikkate alındı. Her iki taraftaki pterygoid işlemin yanal plakasında veya foramen ovale ve foramen lacerum'da yaralanma gösteren kafatasları hariç tutuldu.

Bulgular: Foramen ovale'nin processus pterygoideus lateralis'e göre konumu değerlendirildiğinde, sağ tarafta en fazla tip II (medial tip) %30.3 oranında, sol tarafta ise en fazla tip III (direkt tip) %23.3 oranında bulunmaktaydı. Her iki tarafta en az ise tip IV bulunmaktaydı. Foramen lacerum ise %50 oranında posteromedial olarak direkt medial pterygoid çıkıntı ile ilişki göstermekteydi.

Sonuç: Foramen ovalenin foramen lacerum ve pterygoid çıkıntılardan uzak olması nervus mandibularisin çıkış yerini tespit etmeyi zorlaştıracağı için cerrahi prosedürleri riskli hale getirebilir.

Anahtar Kelimeler: Foramen ovale, Perkutanöz yaklaşım, Foramen lacerum

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INTRODUCTION

The foramen ovale (FO), one of the holes in the ala major of the os sphenoidale, is usually located near the upper end of the posterior border of the lateral pterygoid processes (LLP). It is located posterolateral to the foramen rotundum, anteromedial to the foramen spinosum, and lateral to the foramen lacerum (FL). It connects the fossa cranii media to the fossa infratemporalis. Nervus mandibularis, ramus meningeus accesorius of arteria maxillaris, and sometimes nervus petrosus minor pass through it (1).

FL does not represent a true foramen, meaning the bony canal containing neurovascular structures. The foramen lacerum is a cavity located at the junction of 3 basic structures that make up the skull base (corpus and ala major of os sphenoidale, pars petrosa of os temporale, clival part of os occipitale). Although no major anatomical formation passes through the FL, it is adjacent to important anatomical structures. Arteria carotis interna crosses this hole from above. Nervus canalis pterygoidei (vidian nerve) is formed above the hole and enters the canalis pterygoideus anterior to the FL. In addition, the clinically important ganglion trigeminale (glasser ganglion, semilunar ganglion) sits on the posterior-outer side of the foramen lacerum (2).

Today, endoscopic approaches are accepted as the standard procedure in anterior skull base surgeries. However, pathologies located around the fossa infratemporalis and FO are among the more difficult pathologies in endoscopic approaches. Therefore, approaches such as endoscopic endonasal, transmaxillary, and transpterygoid guide the surgeon (3). From the endoscopic endonasal perspective; The FL is a key structure due to its location at the junction between the sagittal and coronal planes. It is an important point for the endonasal approach, as it is located at the junction of most surgical routes in the coronal plane (4). FO which is located just lateral to the FL, is also an important component of cranial anatomy in neurosurgery. It facilitates anesthesia by providing access to the trigeminus nerve, especially in trigeminal nerve neuralgia (5). In percutaneous procedures aLLPied to the FO, the processus pterygoideus of the os sphenoidale is the guide point used to reach the foramen (6). Since the needle insertion site is adjacent to the trigeminal nerve, complications of this approach have been reported as masseter weakness, decreased corneal reflex, oculomotor nerve palsies, and carotid cavernous fistula (7,8). In addition, the atypical location of FO may cause neuralgias by affecting the adjacent bone structures and the anatomical organization of the nerves passing through it (9-11).

Trigeminal neuralgia is a serious condition that results in penetrating, episodic facial pain, and medical treatments usually give short-term results (12). Today, surgical procedures such as microvascular decompression, glycerol rhizolysis (13), trigeminal ganglion balloon compression and percutaneous stereotactic radiofrequency rhizotomy, which is one of the most risk-free methods of recent years, are aLLPied in the treatment of trigeminal neuralgia (14). However, for the efficient, effective and safe use of these techniques, a complete understanding of the surgical anatomy of the foramen ovale and surrounding structures is required (15). This study was conducted to describe the anatomical variations of the foramen ovale (FO) and to evaluate its relationship with the FL and pterygoid processes.

In summary, skull foramen are of great clinical importance due to variations in their size, location, shape and neurovascular structures passing through them. Knowing these variations helps clinicians in radiology and surgery. This study aims to guide clinicians in percutaneous and endoscopic endonasal approaches, with detailed morphological examination of FO and FL and determination of its clinical relationship with processus pterygoideus.

MATERIAL AND METHOD

This descriptive study was conducted with the skulls found *in Erciyes University and Ankara Medipol University Faculty of Medicine Anatomy* laboratories. The study was carried out with 56 skulls (right and left; 112 in total).

Inclusion criteria: Bones with preserved integrity and no structural defects were included in the study.

Exclusion criteria: Bones with fractures in the basis cranii externa that may affect the foramen ovale and foramen lacerum were excluded from the study.

Research design: The position of the FO relative to the LLP was evaluated with reference to the study of Iwanaga et al. (2018) (6) (**Figure 1**). Also, FO shape was evaluated with reference to the study of Iwanaga et al. (2018) and Elnashar et al. (2019).

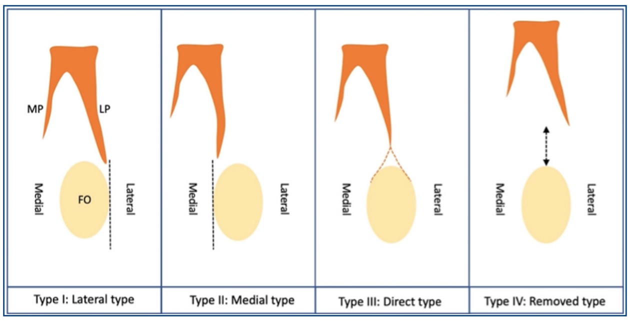

Figure 1. Position of foramen ovale relative to lateral pterygoid processes (6)

On the basis of the relationship between the FO and the posterior border of the base of the lateral plate of the pterygoid process, these were classified into four types (**Figure 2**):

- Type I: the posterior border of the base of the lateral plate ends at or close to the lateral border of the FO
- Type II: the posterior border of the base of the lateral plate of the pterygoid process ends at or close to the medial border of the FO
- Type III: the posterior border of the base of the lateral plate of the pterygoid process ends at or close to the center of the FO
- Type IV: the posterior border of the base of the lateral plate of the pterygoid process ends distant from the FO

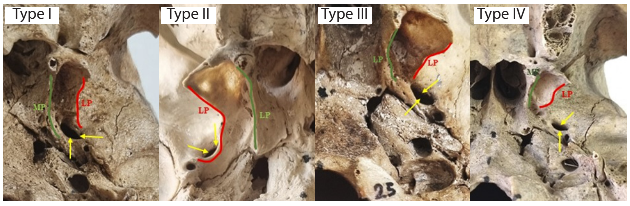

Figure 2. Position of FO relative to LPP.
Type I: Lateral type, Type II: Medial type, Type III: Direct type, Type IV: Far type

The position of the FL relative to the processus pterygoideus medialis (MPP) was classified into 3 groups as a result of the evaluations made by the researcher (**Figure 2**).

- Type I, in which the FL is located posteromedially to the MPP and in front of the inner mouth of the canalis caroticus,
- Type II, which is seen as a thin canal completely closed by the canalis caroticus and located on the posteriomedial of the MPP,
- Type III (**Figure 3**), in which the FL spreads to both sides of the MPP, covering a large area and expanding towards the FO

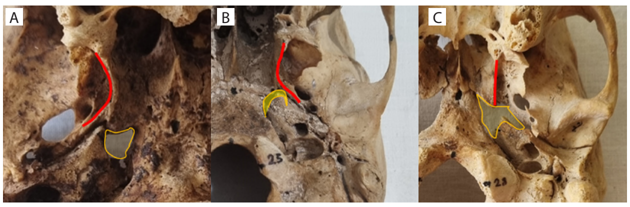

Figure 3. Position of FL relative to MMP
A: Posteromedial-direct, B: Posteromedial- embedded like canal, C: Both side-spread

Statistical Analysis

Basic descriptive statistics were employed to analyze the data were done by the computer software SPSS. The mean, standard deviation and range for each of the measurements were measured. Comparison of the values of all measurements was made between sides of each subject. All measurements and frequencies of the data were tabulated and separated according to the sides. p values less than the 0.05 level of significance was considered to be statistically significant.

RESULTS

In the study, it was determined that FO was seen in oval, almond, triangular and cordate shapes (**Figure 4**).

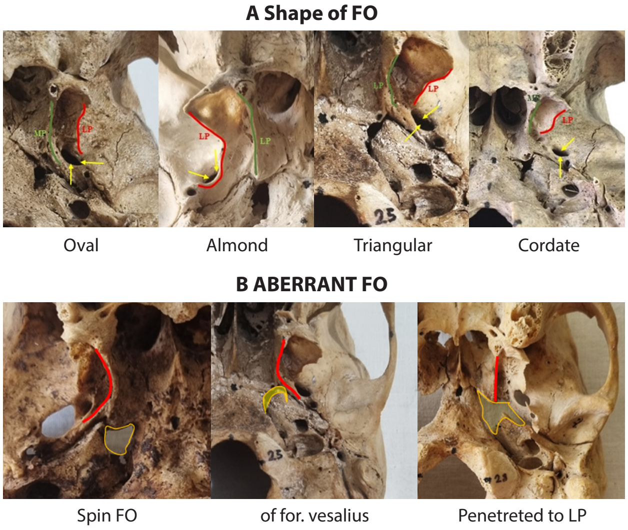

Figure 4. Shape (A) an d Aberrant (B) FO (LP: Lateral processes, MP: Medial processes)

While the oval type, which is the classical FO shape, is most common on the right and left; it was determined that triangular (8.9%) type was observed on the right side and the cordate type (3.5%) was observed on the left side at the lowest rate (**Table 1**).

Table 1. Shapes of FO

Shape of FO	Right	Left	Total	p
Oval	32 (28.5)	34 (30.4)	66 (58.9)	p>0.05
Almond	12 (10.7)	13 (11.6)	25 (22.3)	p>0.05
Triangular	5 (4.4)	7 (6.3)	12 (10.7)	p>0.05
Cordate	7 (6.2)	2 (1.7)	9 (8.1)	P<0.05
Total	56 (50)	56 (50)	112 (100)	

Test: ındependent t testi, p<0.05

Considiring atypical forms of FO (Elongation of the bony prominence into the FO), it was determined that spin-like protrusions tended towards the FO. Also, foramen vesalis were located immediately adjacent to the FO, or a portion of the FO penetrated well into the LP and some of it was located in the LP (**Figure 5**). Regardless of the side (n=112), it was determined that the rate of spin FO was 23.4%, FO accompanied by foramen vesalis was 44.6%, and FO penetrating into the LP was 32%.

When the position of the FO relative to LLP is evaluated, type II (medial type), which is the most common type, is observed with a rate of 30.3% on the right side and 23.2% on the left side; Type III (direct type) was observed in 23.3% on the left side and 13.2% on the right side. It was determined that Type II was observed at a higher rate on the right side (p<0.05). It was determined that Type III was observed at a higher rate on the left side (p<0.05) (**Table 2**).

Table 2. Position of FO relative to PPL

Position of FO relative to PPL	Right (%)	Left (%)	Total (%)	p
Type I (Lateral type)	4 (4.4)	4 (4.4)	8 (7.1)	p>0.05
Type II (Medial (type)	34 (30.3)	26 (23.2)	60 (53.5)	p<0.05
Type III (Direct type)	15 (13.4)	26 (23.2)	41 (36.6)	P<0.05
Type IV (Far type)	3 (3.3)	2 (1.6)	5 (4.4)	p>0.05
Total	56 (50)	56 (50)	112 (100)	

Test: ındependent t testi, p<0.05

It was determined that, on the right side FL was located posteromedial to the MMP at the highest rate (55.3%), and on the left side, it was located in the form of a thin canal under the canalis caroticus at the highest rate (44.6%). FL was expanding towards the FO, including the MMP at a rate of 17.8% on the right and 21.4% on the left (**Table 3**).

Table 3. Position of FL relative to PPM

Position of the foramen lacerum relative to the medial pterygoid process	Right (%)	Left (%)	Total (%)	p
Type I-Posteromedial-direct	31 (55.3)	19 (33.9)	50 (50)	p<0.05
Type II- embedded thin channel	15 (26.7)	25 (44.6)	40 (35.7)	p<0.05
Type III- spread on both sides	10 (17.8)	12 (21.4)	22 (19.6)	p>0.05
Total	56 (50)	56 (50)	112 (100)	

Test: independent t testi, p<0.05

In the FO-FL relationship, without discriminating between parties; In 46.8% of the samples, fissura petrooccipitalis was found together with a thick bone layer between the FO-FL, and in 53.2% of the samples, there was a canal-shaped fissura petrooccipitalis between the FO-FL (**Figure 5**).

Figure 5. FO-FL relationship (Purple line: Lateral processes, Red line: Medial processes)

In our study, it was determined that 65.9% of the FO was in the form of a canal and 34.1% of it was in the form of a hole. In addition, oval (38.5%) and cordate (19.8%) types of FO were mostly observed in the form of canals, while almound (12.8%) and triangular (5.4%) shapes were mostly observed in the form of foramen (**Figure 6**).

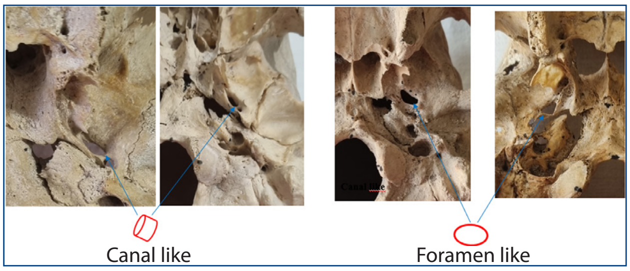

Figure 6. Presence of FO as foramen or canal for the surgical approach

DISCUSSION

Different definitions have been used to determine the position of FO in surgical approaches. Zdilla et al. used the maxillary molar plane and the interemens plane (the line between the bilateral mandibular eminence) and found that these planes passed the FO in more than 80% of cases (16). Peris-Celda et al. reported that the FO is located slightly lateral (2.3 mm) to the posterior base of the pterygoid process and can be accessed with a needle insertion strictly parallel to the sagittal plane as close as possible to the maxilla (17). Iwanaga et al. (2022) reported that in the percutaneous procedure, the location of the FO can be determined more easily by evaluating its position relative to the PL. They classified FO into 4 different types according to its relationship with PL, and reported that in types I and III, it guided the needle to the FO by following the base of the LLP from behind, providing relatively easy access to the FO. They emphasized that while type IV is found in 21% of all parties, it may be difficult to locate the FO of this type due to its disconnection from the base of the lateral plate of the pterygoid process (6). In the classification we made according to the study of Iwnaga et al. (2022), we determined that type II (medial type) was found mostly on the right side (30.3%), and type III (direct type) was found on the left side (23.3%). Type IV was found at the lowest rate, while types II and III were observed at a higher rate on the right side.

There are many studies reporting that the deep location of the FO in the form of a hole or canal in the surgical approach is important for the course of the surgery (18-23). FO morphology has been investigated in many studies. Prakash et al. (10) divided FO into four groups as oval, almond, round and irregular in their study, while Elnashar et al. (7) classified FO into six types as oval, crescent, cordate, almond, longitudinal and round. In our study, FO was divided into four groups as oval, almond, triangular and cordate. Oval type, which is the most classical FO shape, was observed on the right and left, while triangular type (8.9%) was observed on the right side and cordate type (3.5%) was observed on the left side at the lowest rate. In this context, our study is similar to the studies in the literature (1,5,10). We think that it is important to know the morphological shape of the foramen ovale better, especially in terms of avoiding incorrect injections.

It is thought that the spin-like extensions penetrating into the FO are associated with the pterygoid fascia or ligament, and tissue extensions that may be found in this region may cause mandibular nerve compression because they close the hole (18). In addition, it has been reported that the presence of the foramen vesalius may cause confusion for surgeons in operative approaches to FO (19). This foramen variant, particularly when large, may be misidentified as FO on imaging, leading to failure of transfacial approaches to FO. Reymond et al. (2005) reported the rate of foramen vesalius to be 22% (20) while Berlis (1992) stated that it can vary between 12.5-35%. In our study, it was determined that the spin-like protrusions tended towards the FO, or several foramen vesalis were located immediately adjacent to the FO, or a part of the FO penetrated well into the LP and remained under the protrusions of the LP. Regardless of the side (n=112), the rate of spin FO was 23.4%, FO accompanied by foramen vesalius was 44.6%, and FO penetrating into the LP was 32%. Elnaslar et al. (2019) stated that morphometrically, in 7.8% of the samples in FO measurements, obstruction caused by a calcified pterygoid ligament occurred and this ligament penetrated into the FO in the form of a spin-like protrusion (7). They reported that this situation made it difficult to cannulate 8% of the FO, so there was a 12% risk of accidental cannulation of the FL or foramen vesalisus.

Knowledge of endoscopic endonasal distances and landmarks such as foramen ovale, foramen rotundum, and foramen spinosum helps to predict and understand the depth of dissection, especially when extensive pathological processes obscure critical structures and their interrelationships. The distance from the foramen ovale to the pterygoid process helps to estimate the puncture size of the pterygoid process, which can be achieved by avoiding transection of the lateral pterygoid muscle; therefore, it provides less postoperative pain and trismus (11). Our study, when the position of the FO with respect to LLP is evaluated, ıt was observed that type II (medial type), which is the most common form, is seen with a rate of 30.3% on the right side and 23.2% on the left side, and types II have a higher incidence on the right side ($p<0.05$ This study, it was determined that the FL was located directly on the posterior medial of the MMP with a maximum of 55.3% on the right side, and was seen as a thin channel under the canalis caroticus at a maximum rate of 44.6% on the left side. Since the FO is in the form of a canal or hole determines the angle of entry of the cannula in percutaneous surgeries, it is important to know the shape of the FO (21-23). In our study, it was determined that 65.9% of the FO was in the form of a channel and 34.1% was in the form of a hole. In addition, it was determined that oval (38.5%) and cordate (19.8%) types of FO were mostly observed in the form of canals, while almound (12.8%) and triangular shapes were mostly observed in the form of foramen.

CONCLUSION

In most skulls in this study (53.5%), the FO was medial to the PL, while the FL opened directly to the posteromedial of the MPP, and it was easier to reach both the FO and the FL in these examples. However, in 4.4% of cases, the FO was located far from the LP and was difficult to reach. Knowing the shape of FO and its relationship with PL and FO is extremely important for possible safe and effective surgery. Preoperative imaging with 3D head CT can be helpful in estimating the ease of cannulation and surgical procedure and in guiding the determination of surgical procedures to be performed.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of the Ankara Medipol University Non-Invasive Clinical Research Ethics Committee (Date: 02.02.2023, Decision No:E-81477236-604.01.01-445)

Informed Consent: All patients signed the free and informed consent form.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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