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Morphometric Analysis of the Greater Palatine Foramina in the Bosnia and Herzegovina Population

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Abstract

Objective. The goal of this research was to examine the morphological characteristics and exact anatomical positioning of the greater palatine foramen (GPF), with reference to nearby anatomical landmarks. **Material and Method**. The research was performed on dry human skulls belonging to the Bosnian and Herzegovina population, using digital vernier calipers. The study began by noting the GPF's position relative to the maxillary molars, then measuring its distance from the median palatine suture (MPS), the incisive fossa (IF), the posterior border of the hard palate (PBHP), and the posterior nasal spine (PNS). Measurements were conducted bilaterally, and afterwards the data were analyzed using Student's t-test and Chi-squared test. A statistical significance was set at $P<0.05$. **Results**. The statistical analysis revealed that: the distance of the greater palatine foramen (GPF) from the midline is approximately 15.80±1.28 mm on the right side and 15.86±1.19 mm on the left side. The distance of the GPF from the incisive fossa measures about 40.12±2.19 mm on the right side and 40.34±2.08 mm on the left side. The GPF is positioned around 4.00±1.07 mm on the right side and 4.35±1.34 mm on the left side from the posterior border of the hard palate. Lastly, the distance from the GPF to the posterior nasal spine means 17.55±1.99 mm on the right side and 17.61±1.81 mm on the left side in the entire study population. The highest percentage of skulls (73.05%) showed the GPF positioned at the level of the third molar. **Conclusion**. The findings of this study further emphasize the variations in the location of the greater palatine foramen and underline the importance of thorough preoperative assessment in patients undergoing maxillofacial surgeries and regional block anesthesia.

Key Words: Dry Skull ▪ Greater Palatine Foramen ▪ Morphometry ▪ Clinical Anatomy.

Introduction

The greater palatine foramina (GPF) are a pair of bony foramina found at the posterior end of the hard palate close to the third molar teeth. These foramina transmit the greater palatine nerve (GPN) and vessels from the pterygopalatine fossa into the oral cavity (1).

These vital neurovascular structures could potentially sustain injuries during various surgical operations, including intraoral maxillary nerve blocks, repairs for cleft palates, and surgeries involving the maxillary sinus or molar teeth (2).

There are two intraoral methods for performing maxillary nerve blocks in maxillofacial surgeries: the high tuberosity approach and the greater palatine canal approach. Studies have demonstrated that the high tuberosity approach is often associated with issues such as inadequate anesthesia, and a heightened risk of hematoma due to its closeness to the pterygoid venous plexus. The greater palatine canal approach, which reaches the maxillary nerve through the greater palatine foramen, is generally the most effective and widely used technique, as the nerve passes through the pterygopalatine fossa (2, 3).

The use of anesthetic block on the greater palatine nerve was initially documented in 1927 (4) and has since been recommended for surgeries involving the upper molars, the maxillary sinus, and

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the nasal region. However, a common challenge reported with this procedure is the difficulty in accurately locating the greater and lesser palatine foramens, which can result in inadequate anesthesia (5).

Previous studies have shown that successful palatal anesthesia relies on correctly identifying the location of the greater palatine nerve (5). This is the reason why many researchers, among them Viveka et al., have concluded that the utilization of multiple anatomical reference points, such as the incisive foramen, the midline maxillary suture, and the second and third maxillary molars, simplifies identification of the GPF (6). Due to the lack of sufficient information in traditional anatomy and anesthesiology textbooks regarding the precise location of the greater palatine foramen, our study was initiated to determine its exact positioning within the population of Bosnia and Herzegovina.

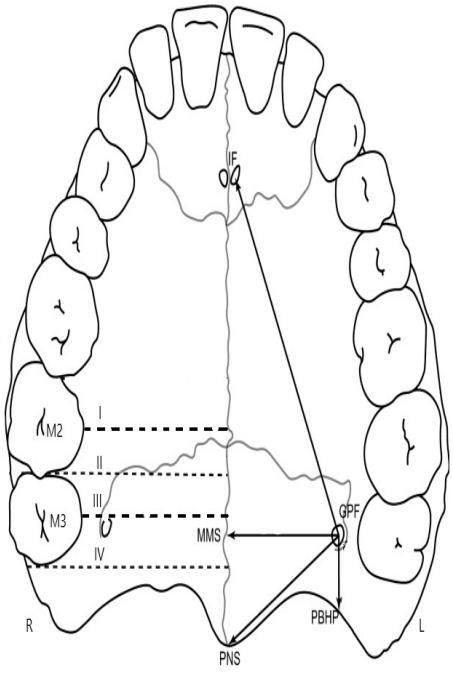
It is our goal that this research will benefit dentists and maxillofacial surgeons in their professional activities, aiming to reduce the incidence of unintended damage to the greater palatine nerves and blood vessels.

Materials and Methods

This research aimed to ascertain the location of the GPF in relation to several anatomical landmarks. The study was performed on 130 adult dry skulls (75 males and 55 females) belonging to the Bosnian and Herzegovinian population, kept at the Department of Anatomy, Faculty of Medicine, University of Sarajevo. All the skulls had fully erupted third molars and were devoid of pathological changes.

Morphometric measurements were conducted using digital vernier calipers (0-1000 mm), 0.05 mm, Metric 530-502, (Mitutoyo Corporation, Japan), with an accuracy of 0.01 mm. Each measurement was taken three times, and the mean was used for subsequent analysis. Additionally, all measurements were recorded by the same individual to reduce methodological errors. Once all the samples were measured, 20% of randomly selected samples were re-evaluated by an observer who had not been involved in the initial assessment. Interclass correlations (ICC) were calculated, showing a very high level of agreement between the evaluations (ICC = 0.92–0.96). The following measurements were taken (Schema 1):

- Distance from the greater palatine foramen (GPF) to the median palatine suture (MPS), (GPF - MPS)
- Distance from the GPF to the posterior nasal spine (PNS), (GPF - PNS)
- Distance from the GPF to the posterior border of the hard palate (PBHP), (GPF - PBHP)
- Distance from the GPF to the incisive foramen (IF), (GPF - IF)
- Location of the GPF in relation to the second (M2) and third (M3) maxillary molars



Schema 1. This illustration of the hard palate demonstrates the greater palatine foramen's location in relation to anatomical landmarks and the maxillary molars. On the left, the distances from the GPF to four major anatomical features (IF, MPS, PBHP, PNS) are shown, while the right side reveals the pooled prevalence of the GPF's position concerning the maxillary molars, (I-IV). Terminology: GPF - greater palatine foramen, IF - incisive foramen, MPS – median palatine suture, PBHP - posterior border of hard palate, PNS - posterior nasal spine; Positions: I – medial to the second maxillary molar, II – between the second and third maxillary molars, III – medial to the third maxillary molar, IV – behind the third maxillary molar.

The spatial relationship of the greater palatine foramen concerning the upper molars was recorded as being either aligned with the longitudinal axis of the maxillary second molar (I), the third molar (III), positioned between the second and third molars (II), or situated behind the maxillary third molar (IV) (7).

Statistical Analysis

All statistical analyses were performed with SPSS version 19 (SPSS Inc., Chicago, IL, USA), while data were compiled using Microsoft Excel 2020 (Microsoft Corp., Redmond, WA, USA) and displayed in tables. Descriptive analysis helped to determine mean and standard deviation. The Student's t-test and Chi-square test (χ^2) were employed to assess whether there were statistically significant differences based on sides and sex. A P-value below 0.05 was regarded as statistically significant for this research. The level of significance was evaluated using P-values, with the following classifications: P≥0.05 denotes non-significant results, P≤0.05 denotes significant results, P≤ 0.01 denotes highly significant results, and P≤0.0001 denotes very highly significant results.

Results

All the skulls that were investigated displayed one greater palatine foramen on both sides. Table 1 provides a summary of the linear measurements of the greater palatine foramen in relation to surrounding anatomical landmarks.

The mean distance from the greater palatine foramen to the median palatine suture was 15.80±1.28 mm on the right side and 15.86±1.19 mm on the left side. The mean distance to the posterior border of the hard palate was 4.00±1.07 mm on the right and 4.35±1.34 mm on the left. The distance from the greater palatine foramen to the incisive fossa measured 40.12±2.19 mm on the right and 40.34±2.08 mm on the left. For the posterior nasal spine, the distances were 17.55±1.99 mm on the right and 17.61±1.81 mm on the left. Statistically significant differences by sex were

Table 1. Distance of the Greater Palatine Foramen from Anatomical Landmarks

Measurements	Side (mm)	Sex	Mean±SD	t-value	P-value*
GPF – MPS	Right	Male	16.20±1.24	1.326	0.188
		Female	15.40±1.32		
	Left	Male	16.28±1.06	1.058	0.292
		Female	15.43±1.31		
GPF – PNS	Right	Male	18.01±2.05	1.426	0.160
		Female	17.08±1.93		
	Left	Male	18.12±1.80	1.326	0.732
		Female	17.10±1.82		
GPF – PBHP	Right	Male	4.05±1.26	8.052	0.0001
		Female	3.95±0.88		
	Left	Male	4.50±1.03	8.986	0.0001
		Female	4.19±1.64		
GPF – IF	Right	Male	41.20±1.10	2.772	0.008
		Female	39.03±3.27		
	Left	Male	41.28±1.06	2.153	0.008
		Female	39.40±3.09		

*Student's t - test; GPF=Greater palatine foramen; MPS=Median palatine suture; PNS=Posterior nasal spine; PBHP=Posterior border of hard palate; IF=Incisive foramen.

Table 2. Variations in the Position of the Greater Palatine Foramen Relative to the Upper molars.

Side	Position	Gender (N; %)		Total	Chi – square	P–value*
		Male	Female	N (%)		
Right	I	8 (57.1)	6 (42.9)	14 (10.8)	1.2625	0.738
	II	11 (64.7)	6 (35.3)	17 (13.1)		
	III	50 (52.1)	46 (47.9)	96 (73.8)		
	IV	2 (66.7)	1 (33.3)	3 (2.3)		
Left	I	8 (61.5)	5 (38.5)	13 (10.0)	2.6972	0.775
	II	12 (57.1)	9 (42.9)	21 (16.2		
	III	49 (52.1)	45 (47.9)	94 (72.3)		
	IV	1 (50.0)	1 (50.0)	2 (1.5)		

*Chi-square test; I=Medial to the second maxillary molar; II=Medial to and between the second and the third maxillary molar; III=Medial to the third maxillary molar; IV=Medial to and behind the third maxillary molar.

Figure 1. a) Greater palatine foramen situated medially to third maxillary molar; b) Greater palatine foramen situated medially to and between second and third maxillary molars; c) Greater palatine foramen situated medially to second maxillary molar; M1= First maxillary molar; M2=Second maxillary molar; M3=Third maxillary molar.

detected for the distances of the GPF to PBHP (P=0.0001) and the GPF to IF (P=0.008), being significantly larger in males.

The frequencies of the greater palatine foramen's positions in relation to the upper molars are summarized in Table 2. Statistical analysis of the obtained results did not show any statistical significance in the results in relation to side or sex.

The dominant position on both sides was in line with the maxillary third molar (73.05%), followed by between the second and third molars (14.64%). Collectively, these positions represented 87.7% of cases (Figures 1 and 2). Positions at the level of the second maxillary molar and behind the third maxillary molar were noted in 6.15% of cases (Figure 3).

Discussion

The greater palatine foramen (GPF) is responsible for carrying the greater palatine nerve, which innervates the posterior section of the hard palate (1). Performing an anesthetic block for this nerve is strongly recommended for surgeries related to the upper molars, the maxillary sinus, and the nasal region (3). Nonetheless, a common issue with anesthesia is the challenge of accurately identifying the location of the greater palatine foramen, often leading to insufficient anesthetic delivery (5). Matsuda first identified the GPF's location in 1927 (8), and since that time, numerous studies have aimed to establish its position variability.

Our research revealed that the mean distance from the greater palatine foramen (GPF) to the midline maxillary suture (MPS) was 15.80 mm on

the right and 15.86 mm on the left. These distances are shorter than the measurements reported in studies of Serbian (9), Thai (10), Turkish (11), Polish (12), Italian (13), and Chinese (14) populations. Conversely, our measurements exceeded those observed in Nigerian (7), South Indian (15), East Indian (16), Brazilian (17), Iraqi (18), Greek (19), and South Indian (20) populations.

Table 3 visually depicts the comparison of our findings with data from other studies.

Additionally, our study found that the mean distances from the greater palatine foramen (GPF) to the posterior margin of the hard palate were 4.00 mm on the right side and 4.35 mm on the left side. These measurements were lower than those reported for Poles (12), Iraqis (18), and Greeks (19). In contrast, they were higher than distances found in Nigerians (7), Serbs (9), Thais (10), Italians (13), East Indians (16), Brazilians (17), and South Indians (20), and similar to measurements reported for Turks (11), Chinese (14), and South Indians (15), (see Table 3).

Table 4 presents a comparison of the distances from the GPF to the posterior nasal spine (PNS) and the infraorbital foramen (IF).

In the Bosnian and Herzegovinian population, the greater palatine foramen was found to be medial to the third maxillary molar in 73.05% of cases, consistent with similar findings in Nigerians (7), Indians (7, 24), Thais (10), South Indians (15, 20), East Indians (16), Iraqis (18), individuals of Negroid descent (25), Kenyans (26), and Brazilians (27). However, Chinese populations predominantly exhibited the greater palatine foramen located between the second and third molars (14).

Interestingly, the second most common position of the greater palatine foramen in individuals of South Africans (25) and Brazilian (27) descent was distal to the third maxillary molar. Conversely, in Nigerians (7), Indians (7, 24), Thais (10), South Indians (15, 20), East Indians (16), Iraqis (18), and Kenyans (26), it was commonly found between the second and third maxillary molars (refer to Table 5 for details). The results of the present study underscore the racial variations in the location of the greater palatine foramen concerning the upper molars among different populations. This variation in positioning may be a result of ethnic influences.

Table 3. Comparison between Studies on the Distances GPF-MPS and GPF-PBHP

References	Population	GPF - MPS (mm)		GPF – PBHP (mm)	
		Right	Left	Right	Left
Present study	Bosnia and Herzegovina	15.80	15.86	4.00	4.35
Ajmani (7)	Nigerian	14.70	14.60	3.70	3.70
Radošević et al. (9)	Serbian	15.99	15.88	2.01	2.10
Methathrathip et al. (10)	Thai	16.20	16.20	2.10	2.10
Cagimni et al. (11)	Turkey	16.30	16.10	4.20	4.00
Tomaszewska et al. (12)	Polish	16.10	15.60	4.90	4.80
Gibelli et al. (13)	Italian	16.40	16.80	3.80	3.80
Wang et al. (14)	Chinese	16.00	16.00	4.11	4.11
Saralaya et Nayak (15)	South Indian	14.70	14.70	4.20	4.20
Westmoreland and Blanton (16)	East Indian	14.80	15.00	1.90	1.9 0
Lopes et al. (17)	Brazilian	15.60	15.40	3.38	3.50
Jaffar and Hamadah (18)	Iraqi	15.70	15.70	4.90	4.90
Piagkou et al. (19)	Greek	15.30	15.30	4.60	4.70
Vinay et al. (20)	South Indian	14.80	14.80	3.58	3.56

GPF=Greater palatine foramen; MPS=Median palatine suture, PBHP=Posterior border of hard palate.

Table 4. Comparison between Studies on the Distances GPF-PNS and GPF-IF

References	Population	GPF - PNS (mm)		GPF – IF (mm)	
		Right	Left	Right	Left
Present study	Bosnia and Herzegovina	17.55	17.61	40.12	40.34
Viveka and Kumar (6)	Indian	17.78	17.44	39.76	39.37
Tomaszewska et al. (12)	Polish	17.00	17.00	34.00	34.30
Saralaya et Nayak (15)	South Indian	0.00	0.00	37.20	37.30
Vinay et al. (20)	South Indian	0.00	0.00	36.60	35.70
Awad et al. (21)	Egypt	16.55	16.48	38.06	37.96
Ortug et al. (22)	Turkey	15.84	15.84	38.27	38.27
Singht et al. (23)	North Indian	13.60	13.77	37.39	37.09

GPF=Greater palatine foramen; PNS=Posterior nasal spine, IF=Incisive foramen.

Table 5. The Percentage of Opening of the GPF in Relation to the Maxillary Molars

Researchers	Population	I (%)	II (%)	III (%)	IV (%)
Present study	Bosnia and Herzegovina	10.40	14.65	73.05	1.90
Ajmani (7)	Nigerian	13.07	38.46	48.46	0.00
Ajmani (7)	Indian	0.00	32.35	64.69	2.94
Methathrathip at al. (10)	Thai	7.00	14.10	71.90	7.00
Wang et al. (14)	Chinese	17.00	48.50	33.50	0.00
Saralaya and Nayak (15)	South Indian	0.40	24.20	74.60	0.80
Westmoreland and Blanton (16)	East Indian	9.70	33.60	50.70	6.00
Jaffar and Hamadah (18)	Iraqi	12.00	19.00	55.00	14.00
Vinay et al. (20)	South Indian	3.67	19.00	76.00	1.33
Kumar et al. (24)	Indian	5.00	9.00	85.00	1.00
Langenegger et al. (25)	South Africa	1.00	3.00	62.00	34.00
Hassanali and Mwaniki (26)	Kenyan	10.40	13.60	76.00	0.00
Chrcanovic and Custodio (27)	Brazilian	0.00	6.19	54.87	38.94

I=Medial to the second maxillary molar; II=Medial to and between the second and the third maxillary molar; III=Medial to the third maxillary molar; IV=Medial to and behind the third maxillary molar.

Conclusion

This is, to our knowledge, the first investigation into the anatomical variations of the greater palatine foramen (GPF) among the population of Bosnia and Herzegovina. The results are essential for comparing Bosnian and Herzegovinian skulls with those of other ethnicities and regions. Furthermore, this information will aid anesthetists in accurately locating the GPF, thereby enhancing surgical outcomes.

What Is Already Known on This Topic:

In clinical dentistry and maxillofacial surgery, a maxillary nerve block is performed to achieve hemimaxillary anesthesia. This involves administering local anesthesia to the maxillary nerve, which is a branch of the trigeminal nerve or one of its subdivisions. The most common method for maxillary nerve block is via the greater palatine canal (GPC), which leads to the pterygopalatine fossa, where the trunk of the maxillary nerve is situated. This GPC method is favored in clinical settings because it has a high success rate and a low incidence of postoperative complications. The effectiveness of this procedure relies heavily on the position of the greater palatine foramen (GPF), found on the hard palate and serving as the entry point to the greater palatine canal (GPC). Research has indicated that the GPF exhibits various anatomical variations in its location, highlighting the necessity for detailed morphological analysis of the GPF to enhance the success of the GPC approach for maxillary nerve block.

What This Study Adds:

Despite its importance, little is known about the morphological and morphometric characteristics of the greater palatine foramen (GPF) in the population of Bosnia and Herzegovina. The previous research was conducted with the aim of obtaining the most accurate data on the position of the greater palatine foramen (GPF) in relation to anatomical landmarks in the dry skulls of the population of Bosnia and Herzegovina.

Authors' Contributions: Conception and design: AV and ET; Acquisition, analysis and interpretation of data: AV and ET; Drafting the article: AV, ET and EK; Revising it critically for important intellectual content: AV, ET; Approved final version of the manuscript: AV, ET and EK.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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