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Mandibular Canal and the Arrangement of the Neurovascular Bundle Exit Routes in Divergent Populations

Agnieszka Tomaszewska[1], Daniel Psonak[2], Joanna Rudzka[2]

[1] Department of Anthropology, Wroclaw University of Environmental and Life Sciences, Poland
[2] Department of Human Biology, Department of Biological Sciences, University of Wroclaw, Poland

Abstract: *Aim:* In face anatomy and surgery, variation in the presence, number, location, and size of the mental foramen is discussed. Knowledge of the location of the mental foramen canal, which may led due to the possibility of accidental injury of the neurovascular bundle passing through this canal may lead to anesthesia. This study aimed to present selected anatomical features of human mandibles, focusing on the morphology of the mandibular canal and its neurovascular bundle exit in populations with different socio-economic status.

Material and methods: Selected well preserved and unharmed human skulls (N= 169) (50.3% males, 49.7% females) from two populations (rural and outskirts) from Poland were used. Populations differed in socio-economic statuses.

Results: Obvious dimorphic differences in each analyzed population were stated and inter-population differences were observed as well. In an outskirt population sexual dimorphism was more evident. Those differences should be considered when approaching the mandibular canal during anesthetic, surgical and forensic procedures.

Discussion: The occurrence of the mental foramen is relatively constant, but location is variable, and thus, each individual may exhibit a different arrangement of bundle exits. Both the position and the direction of the exit of the neurovascular bundle were similar to other European population. However, differences in localization between those two investigated populations were observed. This may suggest that not only genetic but also environmental factors, such as living conditions and diet (which affects developmental stability), may influence the morphology of the mandibular features.

Key words: cranial openings, mental foramen, mandibular foramen, canal mandible.

Original article

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Introduction

Knowledge of the localization of the craniofacial foramina is of importance, mainly for dental, surgical, anesthetic and cosmetic procedures concerning the human skull (Cutright et al. 2003). Among the variety of skull foramina, mental and mandibular foramina are of greatest interest in both clinical and diagnostic practices.

The human mandible is the largest, strongest, and lowest bone in the face. Its innervation is provided by inferior alveolar nerve, a branch of the mandibular division of trigeminal (CNV) nerve (*nervus trigeminus*), which may be impaired due to, e.g. an accidental injury during dental or surgical procedures. A lesion to CNV may lead to local anesthesia, i.e., half of the mandibular region in the case of branches of the inferior alveolar nerve division (Gray 1985), which is described in detail by Renton et al. (2010).

The functional complexity of the human mandible has contributed to its complex structure, in which foramina and canals responsible for communication between the spaces within the human skull can be distinguished. The mandibular foramen is located in the middle of the mandibular ramus, in the inner (medial) aspect of the mandible. The mental foramen is located lateral to the mental protuberance, usually inferior to the apices of the mandibular first and second premolars. The mental foramen allows entrance of the mental nerve and blood vessels into the mandibular canal (Valente et al. 2012; Łasinski 1993; Samantha and Kharb 2013). Through the mandibular canal runs the inferior alveolar nerve and inferior alveolar artery, which provides blood supply to the lower teeth, periodonts of the buccal side and chin and lower lip (Gray 1985; Drake et al. 2010).

Inter- populations and regional differences in size and location of the mental and mandibular foramina has been reported (Green 1987; Moiseiwitsch and Hill 1998; Nayarana and Prashanthi 2003; Hasan 2012; Shenoy et al. 2012). Thus, its position, size, and number need to be considered before preparing osteotomy and other surgical procedures in the foraminal area. Although different methods of measurements of the mandibular features have been reported, the traditional anthropometric measurements with sliding calipers are most often carried out. However, some research was conducted on roentgenographs. Therefore, we should be aware of small simplification of the obtained measurements, because the results are in 2 D space, and therefore, some of the curvilinear measurements may be simplified. Moreover, anatomical variations may impede observations of some mandibular features, such as the bifid or trifid mandibular canal (Mizbah et al. 2012; Miličević et al. 2021), which may not be detected in panoramic or periapical films (Dario 2002). Its occurrence depends on the assessment method (cone- beam computed tomography or panoramic radiographs) but for anthropological and archaeological field work purposes only macroscopic assessment is useable. Radiographic assessment of mental and mandibular foramina may be tentative. Jacobs et al. (2004) reported the mental foramen was detected on 94% of panoramic radiographs, but clear visibility was only attained in only 49% of the time. Similarly, Yosue and Brooks (1989) observed the mental foramen in 87.5% of the samples, but the foramina were clearly visible only in 64% of the samples. Therefore, computed tomography seems to be the best solution in visualizing the position of the foraminal area. According to Sonick et al. (1994), average linear errors for CT investigation is only 1.8% (compared to 24% for panoramic films and 14% for periapical films).

This study aims to compare selected anatomical features of human mandibles, focusing on the morphology of the mental and mandibular foramina. Since there have been reported inter-populations and regional differences in mandibular morphology, we used 2 populations with different socioeconomic statuses to determine whether environmental (geographical) conditions, e.g., life conditions and diet (which affects developmental stability) in diverse populations can influence the morphology of the mandibular features. This study makes also clinical suggestions to reduce inadvertent damage to the mental and inferior alveolar nerve during surgical procedures or dental approaches in the foraminal area.

Material and methods

The study used 169 adult skulls, held at the Department of Human Biology, University of Wroclaw, Poland. The adult age of the crania was confirmed based on the closure of sphenooccipital synchondrosis. The sex of the individuals was determined based on sexually dimorphic cranial features (Workshop 1980). None of the examined skulls showed signs of cranial deformations, malformations, or trauma.

For the analysis, a selection of 2 populations from the Middle-Western European region with different socioeconomic statuses, were used:

1. An example of the rural population sample from Sypniewo site (Maków County, Masovian Voivodeship, Poland) (Xth – XIIIth centuries) (Sekutowski 2002; Biermann 2006). This sample consisted of 75 skulls 25 (33.0%) skulls which were classified as male and 50 (67.0%) as female.

2. An example of the outskirt population sample from Gródek upon the Bug River (Hrubieszów County, Lublin Voivodeship, Poland) (X^{th-} XIIIth centuries) was examined (Belniak et al., 1961). The sample consisted of 94 skulls 60 (64.0%) classified as male and 34 (36.0%) as female.

Morphometric measurements were conducted using a MicroScribe G2L, a 3D contact scanner (www.e-microscribe.com). The measurements (Tab. 1, Fig. 1) were carried out according to Martin's instructions (Martin et al. 1988) and recorded to two decimal places of a millimeter. Each measurement was conducted twice and an average of 2 measurements was used for statistical analyses using Statistica 13.0 software (StatSoft 2016).

The mean, standard deviation (SD), and variation ranges (minimum-maximum) for each of the measurements were calculated. All variables had a normal distribution (Shapiro–Wilk test; $p>0.05$), mostly with homogeneous variances (Levene's test; $p>0.05$). For paired comparisons, the Student *t*-test was used (in cases where variances were not homogenous- with Cochran-Cox adjustment) or Wilcoxon test as an alternative. For unpaired comparisons, as an alternative, *the U*-Mann Whitney test was used. Pearson correlation coefficient (or Spearman for non- normal distribution of the features) was also calculated. The scale according to Stanisz (1998) was used to apply the strength of the correlation:

$0 < r < 0.1$	very weak correlation
$0.1 \le r < 0.3$	weak correlation
$0.3 \le r < 0.5$	average correlation
$0.5 \le r < 0.7$	high correlation
$0.7 \le r < 0.9$	very height correlation
$0.9 \le r < 1$	almost complete correlation.

Table 1. Measurements taken in the study sample

Martin's et al. (1988) measurement number	Measurements	Description of measurements	Figure 1- measurement number
65	kdl-kdl	intercondylar breadth	1–1
65(1)	kr-kr	distance between coronoid processes	2–2
66	go-go	gonion- gonion distance	3–3
68	gn-go	gnathion- gonion distance	4–3
69	id-gn	infradentale- gnathion distance	4–5
69(2)	CHM2	mandibular corpus height below second molar	13
70	go-cm	mandibular ramus height gonion- caput mandibulae	
70(3)	MID	mandibular incisura depth	8
79	MA	mandibular angle	7
	kdl-kr	distance between condylar and coronoid processes	1–2
	pg- gn	pogonion- gnathion distance	6–4
	id- pg	infradentale- pogonion distance	5–6
	pg- ml	pogonion- formane mentale distance	6–9
	MinCH	minimal corpus height	10
	MaxCH	maximal corpus height	11
	MinMB	minimal mandibular breadth	
	MaxMB	maximal mandibular breadth	
	FMeB	mental foramen breadth	9
	FMaB	mandibular foramen breadth	12
	mb- ml	mandibular foramen and mental foramen distance (mandibular canal length)	

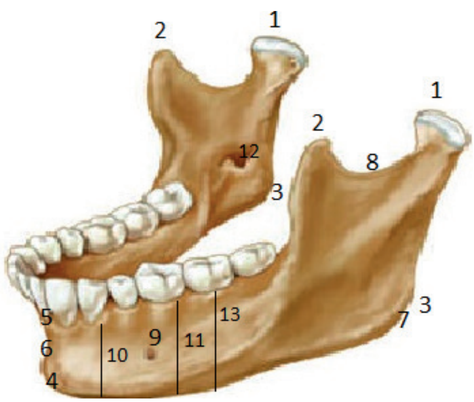

Fig. 1. Measurements taken in the study sample (numbers described in Table 1) (www.legacy.owensboro.kctcs.edu)

Sexual dimorphism was calculated using the formula, where:

$$\text{SexDim} = [(\bar{X}_m - \bar{X}_f) : \bar{X}_f] \times 100\%,$$

$\bar{X}_m$ – male mean, $\bar{X}_f$ – female mean.

The significance level was taken at $p<0.05$ (Stanisz 1998; Field 2006).

Results

For the Sypniewo and Gródek upon the Bug River samples, for unpaired features, significant differences between those two investigated populations were found for 8 features. For the population from the Gródek upon Bug River all features had higher values than those in the Sypniewo population (except for *id-pg*, *go-cm*, and MA, although not significant) (Tab. 2).

Table 2. Differences between two analysed populations (bilateral features were averaged)

Features	Sypniewo			Gródek upon the Bug			Test Z	Test *t*	*Df*	*p*
	$\bar{X}$	SD	N	$\bar{X}$	SD	N				
go-go	95.8	7.1	38	100.5	7.4	41	2.68			**$p^3=0.001$***
pg-gn	14.0	1.8	73	15.7	2.1	91	5.37			**$p^3<0.001$***
id-gn	24.0	3.5	68	25.3	3.3	87		2.4	153	**$p^1<0.001$***
id-pg	9.9	2.8	68	9.9	2.4	87	3.36			$p^3= 0.920$
kdl-kdl	117.7	5.2	29	119.7	6.3	49	4.66			$p^3=0.110$
kr-kr	95.3	6.0	51	97.9	9.9	64	3.81			**$p^3<0.001$***
gn-go	79.1	4.5	55	81.7	7.0	86		3.04		**$p^2=0.002$***
pg-FMeB	23.9	2.6	74	24.4	4.0	92		0.38		$p^2=0.703$
CHM2	21.4	3.2	57	22.0	4.0	89		0.64		$p^2=0.526$
MINMH	18.2	4.5	57	19.9	5.1	91		1.06		$p^2=0.289$
MAXMH	22.3	5.5	57	24.4	5.9	91		1.04		$p^2=0.263$
kdl-kr	42.2	4.0	57	43.0	4.6	87		1.05		$p^2=0.292$
MID	12.1	1.4	55	12.5	1.9	84		2.37		**$p^2=0.018$***
MA	138.2	5.6	50	135.3	6.8	86		1.9		$p^2=0.058$
MinMB	11.1	1.4	75	12.0	1.5	94		1.28		$p^2=0.202$
MaxMB	14.6	1.6	75	15.4	1.6	94		2.38		**$p^2=0.017$***
mb-ml	56.7	3.8	73	59.0	4.0	88		1.55		$p^2=0.120$
FMeB	3.4	1.2	75	3.9	0.9	94		2.42		**$p^2=0.016$***
FMaB	2.7	0.6	74	3.5	1.7	92		0.05		$p^2=0.960$
go-cm	60.2	6.6	49	59.2	9.9	77		0.14		$p^2=0.889$

p^2- Wilcoxon's test, p^3- U-Manna Whitney's test

After controlling for sex, even more features were found to differ significantly. Sexual dimorphism for Sypniewo population was 7.0% and for Gródek upon the Bug River 7.5%. Descriptive statistics are presented in Tables 3 and 4 for Sypniewo and Gródek located along the Bug River respectively. Right and left side measurements were higher for males in both populations (except for FMaB in the Sypniewo sample) (Tab. 3 and 4). Comparisons of bilateral features has revealed significant differences in both sexes for few features, but only in the population from the Gródek upon the Bug River (Tab. 5). In contrast, in the Sypniewo sample, no significant differences between sides were observed.

When mandibular features were compared, a high correlation was also found between mandibular canal length (mb-ml) and mandibular foramen breath (FMaB) for males in population from Gródek upon the Bug River and Sypniewo. High correlation was also found between mandibular foramen breath (FMaB) and mental foramen breadth in males from the Sypniewo. A weak correlation was found between FMaB and FMeB for males from the Gródek upon the Bug River and for females from both populations for mental canal length and FMaB. No statistically significant correlation was found between mandibular canal length and FMeB in both populations (Tab. 6).

Table 3. Descriptive statistics for male and female skulls in the Sypniewo population [in mm]

Features	Body side	FEMALES				MALES				Test Z**	Test C*	*df*	*p*
		$\bar{X}$	SD	N	Ranges min-max	$\bar{X}$	SD	N	Ranges min-max				
go-go		94.1	7.4	22	85-114	98.2	6.3	16	90-107				
pg-gn		13.4	1.5	50	11-17	15.3	1.7	23	11-18	4.09			<0.01
id-gn		23.1	2.9	46	16-29	26.1	3.9	22	19-34		3.53	66	<0.01
id-pg		9.4	2.5	46	4-16	10.7	3.2	22	5-17				
kdl-kdl		115.2	3.8	18	110-125	121.9	4.7	11	112-129	3.12			<0.01
kr-kr		94.1	5.6	35	82-105	97.9	6.3	16	85-106		2.14	49	0.037
gn-go	right	77.5	3.7	30	70-86	80.9	4.2	21	74-89	2.99		49	<0.01
gn-go	left	78.0	4.3	24	70-86	80.9	5.5	19	72-90	2.00			0.045
pg-FMeB	right	23.6	1.8	49	19-29	25.3	1.5	24	23-29	3.73			<0.01
pg-FMeB	left	23.9	1.7	49	19-27	25.1	1.3	24	22-28	2.74			0.06
CHM2	right	20.7	3.1	37	15-26	23.0	3.6	19	16-31	2.41			0.016
CHM2	left	20.5	3.0	36	16-29	22.6	3.4	15	16-28				
MinMH	right	19.5	2.8	37	12-24	21.7	3.4	18	17-29	2.12			0.034
MinMH	left	19.1	2.1	36	15-24	21.8	2.6	12	17-25				
MaxMH	right	23.8	2.5	37	17-29	27.3	3.7	18	22-34	3.30			<0.001
MaxMH	left	23.9	2.8	36	19-31	26.4	4.1	12	20-34				<0.001
kdl-kr	right	41.2	3.3	29	35-48	43.2	4.7	16	36-50				
kdl-kr	left	41.7	3.7	28	34-49	43.5	4.4	14	37-50				
MID	right	12.0	1.4	26	10-15	12.8	1.5	15	10-15				
MID	left	11.9	1.2	27	10-14	12.4	1.8	14	9-15				
MA	right	138.0	5.2	23	129-147	138.6	6.5	18	130-152				
MA	left	138.2	5.0	18	130-147	138.4	6.9	14	128-153				
Min MB	right	10.8	1.4	49	8-14	11.9	1.4	25	10-14	2.71			0.007
MinMB	left	10.7	1.1	49	8-14	11.8	1.8	24	9-16				<0.001
MaxMB	right	14.4	1.8	49	10-17	14.7	1.5	25	11-18	2.73			0.006
MaxMB	left	14.5	1.7	49	10-18	15.1	1.6	24	12-19		5.69	68	0.001
Mb-ml	right	55.0	2.5	48	50-61	59.4	3.8	22	51-66		5.03	62	<0.001
Mb-ml	left	55.4	2.8	43	46-61	59.8	4.1	21	52-67				<0.001
FMeB	right	3.4	1.3	50	1-6	3.6	1.4	24	2-7				
FMeB	left	3.3	1.3	49	1-7	3.2	1.3	25	1-21				
FMaB	right	2.7	0.6	48	2-4	2.9	0.9	23	2-5				
FMaB	left	2.8	0.5	45	2-4	2.7	0.8	21	1-4				
go-cm	right	59.0	3.6	22	52-67	64.7	4.4	17	59-73		4.52	37	<0.001
go-cm	left	57.8	3.8	18	50-65	64.1	4.8	14	58-73		4.18	30	<0.001

*Test C- Cochran- Cox' adjustment; **Test z- U Mann- Whitney test

Table 4. Descriptive statistics for male and female skulls in the Gródek upon the Bug River population [in mm]

Features	Body side	FEMALES				MALES				Test Z**	Test C*	*df*	*p*
		$\bar{X}$	SD	N	Ranges min-max	$\bar{X}$	SD	N	Ranges min-max				
go-go		98.2	5.5	15	90-106	101.9	8.2	26	84-115				
pg-gn		15.1	1.8	33	11-18	16.1	2.2	58	11-22		2.29	89	0.024
id-gn		23.8	2.4	31	19-29	26.2	3.4	56	17-32		3.48	85	0.001
id-pg		8.8	2.3	31	5-14	10.5	2.3	56	5-17	3.10			0.002
kdl-kdl		116.3	4.3	21	106-126	122.3	6.5	28	106-133		3.66	47	0.001
kr-kr		94.7	13.3	26	34-108	100.1	6.0	38	85-111	2.15			0.032
gn-go	right	82.1	6.4	17	73-93	83.4	6.5	40	74-100	2.00			0.045
gn-go	left	79.8	6.0	28	73-99	82.5	5.8	40	71-96				
pg-FMeB	right	25.1	2.0	31	22-28	25.5	2.2	57	21-30				
pg-FMeB	left	25.3	1.9	32	21-29	25.6	2.2	57	23-31				
CHM2	right	21.3	2.8	29	15-27	22.9	3.3	51	15-29		2.42	82	0.018
CHM2	left	21.5	2.4	32	16-26	23.1	3.2	52	17-30				
MinMH	right	20.9	2.3	28	17-27	22.6	3.3	52	12-31		2.46	78	0.016
MinMH	left	21.6	2.1	31	18-26	22.1	3.0	54	12-27				
MaxMH	right	25.5	2.3	29	22-32	27.9	3.0	52	21-33	3.66			<0.001
MaxMH	left	25.7	2.5	30	22-33	27.3	2.8	54	22-33	2.51			0.012
kdl-kr	right	40.9	3.7	27	32-47	44.2	3.8	46	36-52	3.43			<0.001
kdl-kr	left	41.4	3.9	27	33-48	44.7	3.4	44	36-50	3.30			<0.001
MID	right	12.0	1.4	24	10-15	12.8	2.2	45	9-18				
MID	left	11.7	1.6	28	9-15	13.3	2.2	38	9-20	3.02			0.003
MA	right	137.5	6.5	17	126-150	134.0	8.0	40	106-145				
MA	left	136.5	7.2	29	123-150	135.5	7.0	39	119-151				
Min MB	right	11.2	1.1	33	9-14	12.6	1.5	58	9-16	4.41			0.003
MinMB	left	11.2	1.3	32	9-14	12.4	1.6	59	9-16	3.26			0.001
MaxMB	right	14.7	1.2	33	12-17	15.6	1.8	58	12-20	2.09			0.036
MaxMB	left	15.1	1.2	32	13-17	15.9	1.7	59	12-21	2.57			<0.010
Mb-ml	right	56.6	3.9	30	48-63	60.0	4.1	52	52-68	3.09			<0.001
Mb-ml	left	57.6	4.1	30	50-66	60.2	4.3	50	47-69		2.68	78	<0.001
FMeB	right	3.7	0.8	32	2-6	4.0	1.0	59	2-6				
FMeB	left	3.7	1.0	33	2-6	3.8	1.0	58	2-6				
FMaB	right	3.1	0.9	31	2-5	4.0	3.9	52	2-31				
FMaB	left	3.0	0.8	30	2-5	3.6	0.9	50	2-6	2.43			0.015
go-cm	right	59.3	3.3	16	52-63	64.5	6.4	34	48-87	2.94			<0.001
go-cm	left	59.8	4.4	25	50-66	63.9	4.7	34	54-74		3.36	57	0.001

*Test C- Cochran- Cox' test; **Test z- U Mann- Whitney test

Table 5. Bilateral features in males and females (those with significant differences only in population from the Gródek upon the Bug River

Features	Right side *X*	SD	N	Left side *X*		N	Test t	*Df*	*p*
				MALES					
gn-go	83.4	6.5	40	85.2	5.8	40	2.48		0.013[1]
MaxMH	27.8	2.9	52	27.3	2.8	54	2.00		0.046[1]
MID	12.8	2.2	45	13.3	2.2	38	2.63	29	*0.013*[2]
FMeB	4.0	1.0	59	3.8	1.0	58	1.97	87	*0.026*[2]
				FEMALES					
gn-go	82.1	6.4	17	79.8	6.0	28	2.22	25	*0.026*[1]
MinMH	20.9	2.3	28	21.6	2.1	31	2.17	25	*0.040*[2]
MA	137.5	6.5	17	136.5	7.2	29	2.13	25	*0.030*[1]
go-cm	61.4	4.2	16	62.2	4.2	25	2.09	25	*0.037*[1]

[1]- Wilcoxon' test; [2]- Student *t*-test

Table 6. Spearman's and Person's correlation coefficients for mandibular features in populations from Sypniewo and Gródek upon the Bug River

Cecha	MALES		FEMALES	
	mb-ml	FMeB	mb-ml	FMeB
		GRÓDEK UPPON BUG RIVER		
mb-ml	—	r_s=0,01	—	r_s=0,21
FMaB	r_s=0,57*	r=0,32*	r_s=0,36*	r=0,23
		SYPNIEWO		
mb-ml	—	r_s=0,21	—	r_s=-0,09
FMaB	r_s=0,50*	**r_s=0,55***	**r_s=0,37***	r_s=0,24

r_s- Spearman's correlation coefficient; r- Pearson's correlation coefficient; * **p≤0,05**

For male individuals from the Grodek upon the Bug River population statistically significant weak or moderate correlation was observed between *mb-ml* measurement and: *go-go, pg-gn, id-gn, gn-go, MinMB, MaxMB and MID* and for FMaB with *kdl-kr* and MA as well. In addition, a high correlation (0.6) was observed between FMaB and go-go (Tab. 6). For females, statistically significant and moderate correlation was found between mb-ml and MAxMB as well as between mb-bl and pg-FMaB and between FMaB and go-gndl-kr, MinMB and go-cm. High correlation (0.5) was fount between FMaB and MA measurements (Tab. 7 and 8). For males from a population from Sypniewo average correlation was found between mb-bl and kdl-kr. High correlation was also found between mb-bl and MID. For females, mb-ml was moderately correlated with gn-go and CHM2 (Tab. 7 and 8).

Table 7. Spearman's and Person's correlation coefficients for unpaired mandibular features in populations from Sypniewo and Gródek upon the Bug River

	Feature	go-go	pg-gn	id-gn	id-pg	kdl-kdl	kr-kr
GRODEK UPON BUG	**MALES**						
	mb-ml	r_s=0.19*	**r_s=0.41***	**r_s=0.30***	r=0.02	r=0.17	r=0.07
	FMaB	r_s=0.06	r_s =-0.03	r_s =0.01	r_s =0.01	r_s =0.05	r_s =-0.11
	FMeB	**r=0.6***	r=0.11	r=0.22	r_s =-0.01	r=0.43	r_s =0.16
	FEMALES						
	mb-ml	r_s=0.23	r_s=-0.16	r_s=-0.26	r_s=0.04	r_s=-0.26	r_s=0.27
	FMaB	r=0.08	r=0.01	r=-0.36	r=-0.14	r=0.35	r_s=0.29
	FMeB	r=0.16	r=0.27	r=0.41	r_s=0.18	r=0.45	r_s=0.24
SYPNIEWO	**MALES**						
	mb-ml	r_s=0.08	r_s=-0.16	r_s=0.02	r_s=0.001	r_s=-0.24	r_s=-0.18
	FMaB	r=0.39	r_s=-0.10	r=-0.26	r=-0.29	r=0.36	r=-0.04
	FMeB	r_s=0.3	r_s=-0.02	r_s=-0.25	r_s=-0.23	r_s=0.33	r_s=0.38
	FEMALES						
	mb-ml	r_s=0.31	r_s=0.19	r_s=-0.13	r_s=-0.11	r_s=-0.03	r_s=0.07
	FMaB	r_s=-0.12	r_s=0.11	r_s=-0.22	r_s=-0.20	r_s=-0.28	r_s=0.09
	FMeB	r_s=-0.04	r_s=0.02	r=-0.08	r=-0.17	r_s=0.30	r_s=0.20

r_{s-} Spearmana correlation coefficient; r_- Pearsona correlation coefficient; * **p≤0,05**

Table 8. Spearman's and Person's correlation coefficients for paired mandibular features in populations from Sypniewo and Gródek upon the Bug River

	Feature	gn-go	pg-FMaB	CHM2	MinCH	MaxCH	kdl-kr	MID	MA	MinMB	MaxMB	go-cm
GRODEK UPON BUG	**MALES**											
	mb-ml	**r_s=0.37***	r_s =0.21	r_s =0.02	r_s =0.03	r_s =0.11	**r_s =0.58***	**r_s =0.37***	r_s =0.18	**r_s =0.48***	**r_s =0.48***	r_s =0.23
	FMaB	r_s =0.27	r_s =-0.01	r_s =0.01	r_s =-0.02	r_s =0.03	**r_s =0.47***	r_s =0.22	**r_s =0.28***	r_s =0.16	r_s =0.21	r_s =0.23
	FMeB	r_s =0.17	r_s =0.18	r_s =-0.01	r_s =0.17	r_s =0.22	r_s =-0.03	r_s =0.33	r_s =0.23	r_s =-0.07	r_s =-0.001	r_s =0.07
	FEMALES											
	mb-ml	r_s=-0.14	**r_s=0.45***	r_s=0.24	r_s=0.22	r_s=0.25	r_s=0.18	r_s=0.10	r_s=-0.01	r_s=0.28	**r_s=0.36***	r_s=-0.01
	FMaB	**r_s=0.35***	r_s=0.34	r_s=0.12	r_s=0.31	r_s=0.32	**r_s=0.36***	r_s=0.33	**r_s=0.50***	**r_s=0.45***	r_s=0.12	**r_s=0.47***
	FMeB	r_s=0.06	r_s=0.28	r_s=0.21	r_s=0.20	r_s=0.30	r_s=0.10	r_s=0.18	r_s=0.06	r_s=0.18	r_s=0.04	r_s=0.10
SYPNIEWO	**MALES**											
	mb-ml	r_s=0.24	r_s=-0.21	r_s=0.32	r_s=0.17	r_s=0.08	**r_s=0.46***	**r_s=0.53***	r_s=0.24	r_s=0.21	r_s=0.25	r_s=0.35
	FMaB	r_s=0.33	r=-0.45	r=0.13	r=-0.20	r=-0.20	r_s=0.17	r=0.02	**r_s=0.48***	r=-0.46	r_s=-0.15	r_s=0.22
	FMeB	r_s=0.01	r_s=-0.25	r_s=-0.26	r_s=-0.32	r_s=-0.33	r_s=-0.17	r_s=0.13	r_s=0.004	r_s=0.10	r_s=-0.02	r_s=-0.12
	FEMALES											
	mb-ml	**r_s=0.41***	r_s=-0.02	**r_s=0.34***	r_s=0.21	r_s=0.16	r_s=0.24	r_s=0.06	r_s=0.11	r_s=0.15	r_s=0.11	r_s=0.35
	FMaB	r_s=0.22	r_s=-0.26	r_s=0.28	r_s=0.15	r_s=0.17	r_s=0.13	r_s=-0.004	r_s=-0.11	r_s=-0.07	r_s=0.16	r_s=0.16
	FMeB	r_s=-0.13	r_s=-0.14	r_s=-0.07	r_s=-0.15	r_s=-0.10	r_s=-0.10	r_s=0.04	**r_s=-0.45***	r_s=-0.13	r_s=0.08	r_s=-0.27

Discussion

Occurrence of the mental foramen is relatively constant, however, the location is variable. Thus, each individual may exhibit a different arrangement of the neurovascular bundle exit. The position and the direction of the exit of the neurovascular bundle were similar to other European populations (Tab. 9, 10). However, differences in localization between the two investigated populations were observed. Thus, it could suggest that not only genetic but also environmental (geographical) factors, such as living conditions (e.g., diet, which may affect developmental stability), may influence the morphology of the mandibular features.

The literature review revealed a broad variety of features characterized by the human mandible (Tab. 9) which may result from both different environmental conditions (e.g., different food accessibility) as well as nutrition culture. In poorer populations, for instance, a scarcity of food may result in the incorrect realization of the bone growth path. Moreover, nutrition culture, such as consistency and type of food, may result in differences in chewing intensity and, therefore, different sizes of the mandible (Raadsheer et al. 1999; Golusik et al. 2005). A secular trend observed in populations from different time ranges is also an important factor influencing the mandible's features.

Table 9. Comparison of studies concerning the morphometry of the mandibular features according to sexes [in mm]

Author, year of publication	N	Population, time ranges	Sex	Features (mean± SD)					
				go-go	id-gn	gn-go	kdl-kdl	MA	go-cm
This study, 2020	50	Poland (Sypniewo), XI-XIIth	Female	94.1±7.4	23.1±2.9	77.6±3.8	115.2±3.8	138.2±5.3	58.2±3.7
	25		Male	98.2±6.3	26.1±3.9	81.2±4.7	121.9±4.7	138.5±6.1	64.6±4.3
	75		TOTAL	95.8±7.1	24.0±3.5	79.1V4.5	117.7±5.2		
This study, 2020	34	Poland (Gródek upon Bug), XIII-XVIth	Female	98.2±5.5	23.8±2.4	80.7±6.4	116.3±4.3	136.2±6.8	59.6±4.0
	60		Male	101.9±8.2	26.2±3.4	82.2±7.4	122.3±6.5	134.8±6.8	64.6±6.0
	94		TOTAL	100.5±7.4	25.3±3.3	81.7±7.0	119.7±6.3		
Mays, 2014	15	Nederland, XIXth	Female	91.1±7.5		69.7±.3.3	113.1±6.3	134.0±8.3	
	17		Male	99.9±6.8		76.3±7.6	116.9±6.9	126.9±8.7	
	15	England, X-XIXth	Female	96.2±7.1		70.5±6.1	116.7±7.7	126.4±6.4	
	17		Male	105.1±7.1		76.2±4.7	124.2±5.7	122.6±9.0	
Purmal et al., 2013	46	Malaisia, XXth	Female	103.9±5.4					
	44		Male	106.7±7.8					
	34		TOTAL	105.2±6.7					
		China, XXth	Female	105.3±6.5					
			Male	108.2±7.5					
	30		TOTAL	106.7±7.1					
		India, XXth	Female	98.7±8.4					
			Male	111.1±10.0					
	26		TOTAL	104.9±11.0					
Simalcsik et al., 2012	299	Romania, XVI-XVIIIth	Female	94.1±7.3	28.6±3.0	66.1±5.1	112.8±7.2		60.2±4.8
	259		Male	104.8±9.0	32.4±3.0	69.1±4.8	123.9±8.4		64.9±5.0
Ongkana et al., 2009	102	Thailand, XXth	Female		28.2±6.5	79.2±4.6	116.1±5.9		62.6±5.6
			Male		28.3±6.1	83.2±5.2	123.8±6.3		68.1±4.4

Author, year of publication	N	Population, time ranges	Sex	Features (mean± SD)					
				go-go	id-gn	gn-go	kdl-kdl	MA	go-cm
Golusik et al. 2005	16	Poland (Złota), II-IIIth BC	Female	94.1±4.6	30.4±5.0	80.0±3.8	113.9±5.6		
	69		Male	99.9±8.4	34.1±3.1	84.6±4.5	118.2±6.9		
	85		TOTAL	97.00	32.0	82.5	116.0		
	24	Poland (Milicz), XII-XIIIth	Female	93.4±4.9	30.9±2.2	83.4±5.1	112.8±8.3		
	22		Male	100.3±7.5	31.8±3.3	86.1±7.0	118.5±7.7		
	47		TOTAL	97.0	31.5	84.5	115.5		
	104	Poland (Gródek upon Bug), XIII-XVIIth	Female	94.6±6.4	27.0±2.7	77.0±4.8	116.2±6.0		
	160		Male	101.5±7.3	30.3±3.0	81.2±4.8	121.7±7.1		
	264		TOTAL	98.0	28.5	79.0	119.0		
	28	Poland (Warsaw), XXth	Female	94.6±6.6	27.5±3.2	77.0±4.3	110.1±6.6		
	70		Male	98.0±7.7	30.3±3.4	83.0±5.0	116.3±6.1		
	98		TOTAL	96.5	29.0	80.0	114.0		
Fabian and Mpembeni, 2002	25	Tanzania Bantu, ??	Female				77.0±3.9		
	25		Male				80.6±3.8		
Puisorua et al., 2006	91	Europe, Near East, Asia, Africa, ??	Female			91.0±3.6[1]			
			Male			114.1±38.9[1]			
			Female			89.0±1.8[2]			
			Male			110.0±3.6[2]			
			Female			95.0±1.67[3]			
			Male			119.0±29.9[3]			
		Zimbabwe, ??	Female			91.0±3.6		128.0	
			Male			114.0±38.9		123.0	
		Nigeria, ??	Female						
			Male						
			TOTAL					118.8	
		Turkey, ??	Female						
			Male						
			TOTAL					120.2	
		USA, ??	Female					126.5	
			Male					127.8	
		Spain, ??	Female						
			Male						
			TOTAL					118.1	
		China, ??	Female						
			Male						
			TOTAL					121.2	
		Romania, ??	Female					125.0±1.2	
			Male					119.0±1.1	

Legend: ??- data unavailable, [1]- full dentition; [2]- uncomplete dentition; [3]- no dentition

In this study, differences between sexes were found in both analyzed populations. However, for the population from Sypniewo (which is considered as rural population), we found fewer features that exhibited significant sex differences. When the sex of the individuals was controlled for the population from Gródek upon the Bug River, sexual dimorphism was observed in even more features and was slightly higher (7.5%) (Tab. 3 and 4). When sexual dimorphism was lower, living conditions, and thus, socioeconomic status of the population, are considered worse. Sexual dimorphism of the human body is well established. It may be the result of the environmental factors and lifestyle; sexual dimorphism may also be the result of genetic factors (Galdames et al. 2008; Mays 2014). Moreover, disorders of the endocrine system may also result in sex differences in the morphology of the human mandible (Piontek 1999) and greater masticatory forces may result in sexual dimorphism of the mandible. In general, there is less sexual dimorphism in body size in populations with poorer socio-economic status and living in unfavorable environmental conditions (Wells 2012; Tomaszewska et al. 2015). This conclusion may be also related to diet and eating habits. Our results support previous studies, which contend that worse environmental conditions may influence cranial morphology and, ultimately, disrupt an individual's skeletal development (Gilligan and Bulbeck 2007; Harvati and Weaver 2006; Pearson 2000; Perez et al. 2007; Wells 2012).

Table 10. Comparison of studies concerning the morphometry of the mandibular features according to body side [in mm]

Author, year of publication	N	Population, time ranges	Body side	Feature				
				go-cm	MA	FMeB	FMaB	Mb-ml
This study, 2020	75	Poland (Sypniewo), XI-XIITh	Right	61.5±4.9	138.3±5.7	3.5±1.3	2.7±0.7	56.4±3.6
			Left	60.6±5.2	138.3±5.8	3.3±1.3	2.6±0.8	56.8±3.9
This study, 2020	94	Poland (Gródek upon Bug), XIII-XVIth	Right	62.8±6.1	135.0±7.7	3.9±0.9	3.7±3.1	58.8±4.3
			Left	62.1±5.0	135.9±7.1	3.8±1.0	3.4±0.9	59.2±4.4
Shenoy et al., 2012	50	India, ??	Right		124.4±6.0			
			Left		124.1±6.2			
Ennes and Monteiro de Medeiros, 2009	99	Brazil, ??	Right		131.8±8.5[1]			
			Left		131.2±8.2[1]			
			Right		125.6±7.8[2]			
			Left		125.7±9.2[2]			
			Right		126.5±7.8[3]			
			Left		125.7±9.2[3]			
Prośba-Mackiewicz et al., 2005	40	Poland, ??	Right	64.0±4.8[4]				
			Left	63.5±4.8[4]				
Oguz and Bozkir, 2002[7]	34	Turkey, ??	Right	65.6±5.0	120.2±4.7			
			Left	64.6±4.2	120.2±3.6			
Rai et al., 2014	40	India, ??	Right			2.6±0.9		
			Left			2.6±0.9		
Hoque et al., 2013	185	Bangladesh, ??	Right			2.6±0.7		
			Left			2.5±0.5		
Agarwal and Gupta, 2011	100	India, ??	Right			3.3		
			Left			3.3		
Junior et al., 2010	50	Brasil, XXth	Right					52.8
			Left					51.6
Singh and Srivastar, 2010	100	Turkey, ??	Right			2.8		
			Left			2.6		
Ilayperuma et al., 2009	51	Sri Lanka, ??	Right			3.3±0.9		
			Left			3.4±0.8		
Oliveira Junior et al., 2009	80	Brasil, ??	Right			2.4±0.6		
			Left			2.4±0.6		
Wychowański et al., 2008.	100	contemporary	Right			3.7±1.0	3.2±0.6	
			Left			3.8±1.0	3.4±0.6	
			Right			3.3±0.7	3.5±0.5	
			Left			3.8±1.1	3.3±0.4	

Author, year of publication	N	Population, time ranges	Body side	Feature				
				go-cm	MA	FMeB	FMaB	Mb-ml
Igbigbi and Lebona, 2005	70	Malawi- ??	Right Left			2.4±0.2 2.7±0.2		
Prośba-Mackiewicz et al., 2005	40	??	Right Left Right Left			2.7±1.0[1] 2.8±1.0[1] 2.9±1.1[4] 2.8±1.0[4]	3.9±0.9[1] 4.0±0.9[1] 4.1±1.8[2] 4.2±1.7[2]	
Goudot, 2002	1	France* - paleolith	Right Left			4.5 4.5		
Goudot, 1999	1	France*- 60000-45000	Right Left			6.0 6.0	5.0 5.0	
Phillips et al., 1992	75	??	Right+ Left			2.9		

Legend: [1] – no dentition; [2] mandibles with 1 to 10 teeth; [3] mandibles with 11 to 16 teeth; [4] partial lack of dentition; * Neanderthal's mandible.

Foraminal area of the mandible is considered as an important region relevant to anatomy, surgery, anthropology and forensic medicine. The position of the mental and mandibular foramina has been reported to vary in populations from different geographical regions. Currently, to our knowledge, there have not been any investigations concerning the position and morphology of these foramina in populations with divergent socio-economic statuses (SES). The SES may influence lifestyle and some behavioral habits regarding food consumption, consumed food type as well as breastfeeding. Developmental stability may also influence dental eruption, and this may possibly influence the position of the mental foramen. Positional change of mental foramen is a combination of osseous growth in the region combined with a mesial drift of the dental anlage. Williams and Krovitz (2004) stated that the mental foramen migrates posteriorly during ontogeny and found that the mental foramen forms prenatally under the anticipated anterior root of the developing first deciduous molar. Williams and Krovitz (2004) also asserted that this position is maintained at birth and remains mostly stable during the deciduous eruption. During the eruption of the second molar, the mental foramen generally migrates to a position inferior to the second premolar (Hasan 2012; Narayana and Prashanthi 2003).

Possible limitations of this study may result from the anatomical variation in the mandibular area especially given that we did not analyze additional/ accessory mandibular and mental foramina in order to show only variation in mental/mandibular foramina and mandibular canal. If a large accessory mental foramen exists, that could make a regular mental foramen smaller than the foramen on contralateral side (if the contralateral side does not have the accessory mental foramen) (Iwanga et al. 2016). We are also aware that in cone-beam computed tomography different aspects of mandibular canal may occur (i.e. bifid or trifid mandibular canal (Naitoh et al. 2007). Bifid mandibular canal exhibits a variety of incidence, ranging from 0,08 to 65% (Mizbah et al. 2012; Miličević et al. 2021), which may not be seen in panoramic or periapical films (Dario 2002). Its occurrence depends on the assessment method (cone-beam computed tomography or panoramic radiographs) but for anthropological and archaeological field works purposes only macroscopic assessment is useable. Hence, this research is based on macroscopic observations and dedicated for field works/ excavations macroscopic examinations, where sophisticated methods are not possible to conduct. As such, this study aimed to facilitate conclusions based on macroscopic observations although for clinical studies this method could not be sufficient. Nevertheless, the results of our study should be considered when sudden and unplanned interventions in this region are conducted.

Conclusion

The results derived from different studies (please see Tab. 9 and 10 for details) may be flawed due to the application of different methods (Hasan 2012). In addition, the observed differences between right and left sides of the mandible may result from chewing habits (unilateral) (Sójka, Hędzelek 2011). Literature reviews revealed that although studies on the morphology and morphometry of mental and mandible foramina are common, research specifically focused on the distances between these foramina and morphology of the mandible canal are rather rare (Tab. 10). In this study we argue that such (methodological) differences should be considered when approaching to the mandibular canal during anesthetic, surgical and forensic procedures.

Conflict of interests

The authors declared no conflicts of interests

Authors' contribution

JR collected the data and performed statistical computations.

DP was project supervisor, co- edited the final version of the manuscript.

AT conceived the paper, performed statistical computations, drafted the manuscript and co- edited the final version of the manuscript.

All authors carefully read and accepted the final version of the manuscript.

Corresponding author

Agnieszka Tomaszewska, Department of Anthropology, Wroclaw University of Environmental and Life Sciences, Poland; e- mail: agnieszka.tomaszewska@upwr.edu.pl

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