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Functional morphometry of the pterygoid hamulus. A comparative study of modern and medieval populations

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Abstract: The pterygoid hamulus (PH) is located in the infratemporal fossa and is part of the pterygoid process of the sphenoid bone. Its location on the cranial base and the multitude of anatomical structures whose attachments lie on the surface of the pterygoid hamulus make it of high functional and topographic significance. Due to insufficient literature on the PH morphometry, we decided to study this issue using modern and archaeological material. In total, 99 observations were subjected to quantitative and qualitative analysis (50 - from modern times and 49 - from medieval times). On the basis of the statistical analysis, statistically significant differences in the length of PH were found with respect to age and sex. Statistically significant differences in the PH width were also noticed with respect to sex and the period of origin. The results obtained may help better understand the development mechanism of the pterygoid hamulus bursitis.

Key words: pterygoid hamulus, cone-beam computer tomography, archeological material

Introduction

The pterygoid hamulus (PH) is an osseous structure located in the lower segment of the medial pterygoid plate of the sphenoid bone (Rusu et al. 2013). The location on the cranial base and the multitude of anatomical structures whose attachments lie on the surface of the pterygoid hamulus make it of high functional and topographic significance. In the macroscopic structure of PH the base, the body, the neck and the head can be distinguished, as well as the lateral and medial surfaces. On the lateral surface there is a shallow groove (*Sulcus hamuli pterygoidei*)

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which is covered with cartilage tissue. Around this place the tensor veli palatini muscle winds (Figure 1).

It is with this muscle that the pterygoid hamulus is most frequently associated (Misuria 1976). However, there are a lot of other structures which are connected with this tiny osseous process. These include the pterygopharyngeal part of the sphincter muscle of the upper pharynx, the pterygomandibular raphe, the buccinator muscle, and the medial pterygoid muscle (Putz and Kroyer 1999). According to some researchers, the pharyngobasilar fascia (Takezawa and Kageyama 2012) and the palatine aponeurosis (Iwanaga et al. 2017) attach to PH in 51%. There is a number of reports in literature which indicate that PH plays an important role in the topography of the so-called transition zone between the palatopharyngeal sphincter muscle and the superior pharyngeal constrictor muscle. The hamulus muscle bundles running in this zone attach to the pterygoid hamulus. These bundles are connected with the palatopharyngeal sphincter muscle and the pterygomandibular part of the superior pharyngeal constrictor muscle (Sumida et al. 2017). According to scanty scientific reports on the development of PH, in children it has an identical macroscopic structure with that in adults but with proportionally smaller dimensions (Putz and Kroyer 1999). The ossification centres of the medial pterygoid plate of the sphenoid bone develop independently of the chondrocranium. Although the main part of the medial pterygoid plate of the sphenoid bone ossifies on the membranous base, the pterygoid hamulus, however, turns into cartilage before ossification (Fawcett 1905).

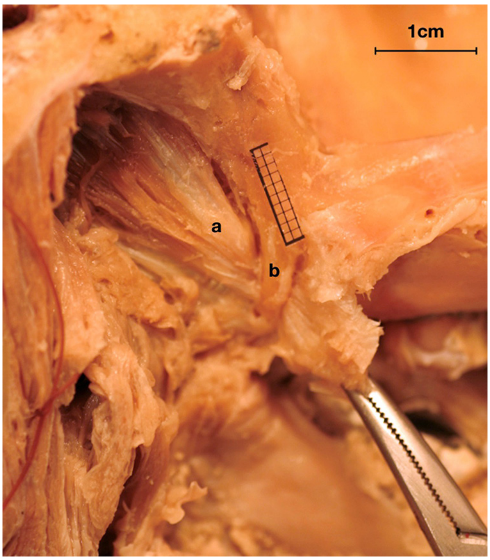

Fig. 1. Pterygoid hamulus preparation (left side)
a. Tensor veli palatini muscle.
b. Pterygoid hamulus.

The histological structure of PH reminds a sandwich consisting of a thicker medial plate and a thinner lateral one. The plates are connected diagonally with the help of the osseous trabeculae running there. In the histological examination it was found that the course of collagen fibers in the medial plate has a more obtuse angle of inclination in relation to the vertical axis than in the lateral plate. The authors believe that PH has a stable structure in both adults and children (Putz and Kroyer 1999). Due to insufficient literature concerning morphometry, we decided to study this issue on modern and archaeological material.

Material and methods

The study was carried out on the basis of the images of cone-beam computer tomography (CBCT) and excavation material. The CBCT images were taken using a Toshiba PCH6500 camera at the Clinical Department of Cranio-Maxillofacial Surgery, Military Institute of Medicine in Warsaw, Poland. The cross-sectional analysis was performed with the help of the Ez3D Plus software. The measurements of the hamulus process: width were taken at the widest point above the column of hamuli and the height from basis hamuli to caput hamuli.

The craniometric material came from the Millennium excavations of Professor Wierciński deposited at the Museum of the Department of Descriptive and Clinical Anatomy of the Medical University of Warsaw. The material included 50 skulls classified in terms of sex, females (F) and males (M) in four age groups: *Juvenis* (14–18/20 years) *Adultus* (20–40 years) *Maturus* (40–60 years) and *Senilis* (over 60 years). The four age groups were then combined in three, (1) up to 30 years old with exclusion of juveniles; (2) 30–60 years old, and (3) 60–90 years old. In order to optimize the results, both off, direct and radiographic measurements were carried out by two researchers and repeated three times. Skulls with a well-preserved pterygoid process were selected and left-sided measurements of heights and widths were performed with the help of a slide-compass with an accuracy of 0.1 mm. Precise determination of the location of the measurements, it was possible to compare the results read with the help of electronic caliper and obtained in computed tomography. In addition, observations of dental alveoli obliteration were noted.

In total, 99 observations were subjected to quantitative and qualitative analysis. The sample group consisted of 46 females and 53 males of which 15 females and 22 males from the age group of up to 30 years old without juveniles, 20 females and 17 males aged 30–60 years, and 11 females and 14 males 60–90 years old. The subgroup from the medieval period (49 observations) included 15 females and 34 males, while from modern times (50 observations) 31 females and 19 males. Thirty seven observations came from people aged up to 30 (including 30 from the Middle Ages and 7 from modern times), 37 from pep- aged 30–60 (including 11 from the Middle Ages and 26 from modern times), and 25 - aged 60–90 (including 8 from the Middle Ages and 17 from modern times) (Table 1 and 2).

The statistical analysis was performed using the statistical package R version 3.4.3. Statistica 2017 for procedure. The Scheirer-Ray-Hare test was ap-

Table 1. Group distribution according to age and sex in modern and medieval populations

Variable	Category	N	Females, n (%)	N	Males, n (%)
Age group (years)	(0,30]		15 (32.6%)		22 (41.5%)
	(30,60]	46	20 (43.5%)	53	17 (32.1%)
	(60,90]		11 (23.9%)		14 (26.4%)
Time period	Medieval times	46	15 (32.6%)	53	34 (64.2%)
	Modern times		31 (67.4%)		19 (35.8%)

Table 2. Age of individuals in modern and medieval populations

Variable	Level		Medieval times		Modern times
age group, n(%)	(0,30]		30 (61.2%)		7 (14.0%)
	(30,60]	49	11 (22.4%)	50	26 (52.0%)
	(60,90]		8 (16.3%)		17 (34.0%)

plied. The calculations were made at the significance level of $\alpha=0.05$ taking into consideration the Benjamini-Hochberg procedure.

Results

Length of the pterygoid process

The analysis of the pterygoid process length was conducted with respect to the following factors: age, sex and period of origin of the observation.

Statistically significant differences were revealed with respect to age. The average lengths in the age subgroups 0–30, 30–60, 60–90 years old were 5.7±0.9 mm, 6.7±2.1 mm, 7.3±2.2 mm respectively ($p=0.008$).

The interaction between the age and sex factors turned out to be statistically significant. Group comparisons showed differences in the length of the pterygoid process with respect to the age group in the female subgroup. Significant differences were stated between the females in age groups 0–30 and 60–90 years old, the average value respectively 5.3±1.1 mm, 8.4±1.8 mm ($p<0.001$), and in age groups 30–60 and 60–90 years old, the average value respectively 6.7±2.1 mm, 8.4±1.8 mm ($p=0.047$). The subgroup of males did not show differences regarding the pterygoid process length in age groups (Figure 2). An interesting observation was the absence of significant differences in the length of the pterygoid hamulus for modern and historical populations.

Width of the pterygoid process

The analysis of the pterygoid process width was conducted with respect to the age factor, sex and period of origin of the observation. Statistically significant differences were shown in the division with regard to sex and period of origin. The average process width for females was 1.8±0.6 mm, while 2.2±0.5 mm for

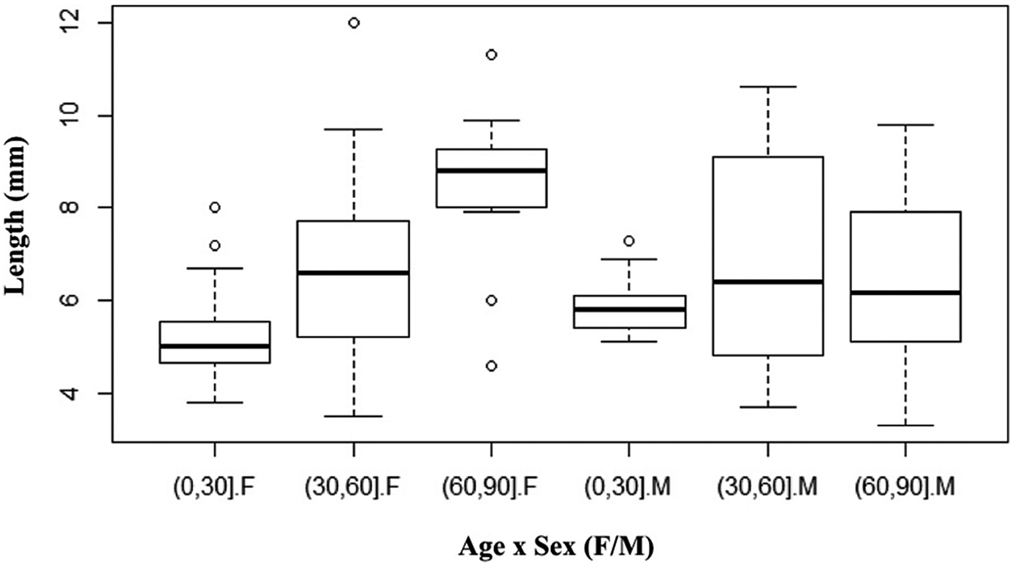

Fig. 2. The association of pterygoid hamulus length with sex and age

males. Statistically significant differences were also found between the observation groups from the Middle Ages and modern times, the average hamulus width was 2.2±0.5 mm and 1.8±0.6 mm, respectively. The interactions of such factors as age, sex and period of origin did not prove statistically significant for the pterygoid process width.

Discussion

Morphometry

According to the morphometric studies conducted by Putz and Kroyer (1999) on 93 adult skulls, 24 children's skulls and 13 radiographs, the average length of PH was 7.2 mm. These results correlate with ours. In addition, we noticed a slight increase with age in the length of the hamulus ($p=0.008$). Since there is no developmental justification, it must have a functional basis. Most likely, larger PH dimensions are connected with changes within the stomatognathic system and may be caused by changes in food intake, respiration or articulation of sounds. It should also be taken into account that the period of old age is often connected with tooth loss. Complete or partial edentulism (especially in the case of lateral teeth missing) in the upper dental arch may be the reason of an increase in PH length against the disappearing alveolar process of the maxilla. One of the common features of patients whose cases are described in literature are missing upper posterior teeth and using dental prostheses (Gores 1964; Hertz 1968; Kronman et al. 1991). In addition, it was discovered that the increase in PH length was particularly distinct in females ($p<0.001$). The PH width in the sagittal plane, according to Putz and Kroyer (1999), was 1.4 mm, while in the frontal plane – 2.3 mm. The above parameters are comparable with the results obtained in the present study. At the same time, we found that in males PH was slightly wider ($p<0.001$), while in the modern population PH was slightly narrower than in the medieval population ($p<0.001$).

Functional aspect

The key to understanding the difference in PH formation is understanding the influence of all the numerous structures with which the pterygoid hamulus is connected. According to the literature, the muscles that attach to the hamulus exert pressure on it in the dorsal and medial directions. The pterygomandibular raphe exerts pressure in the dorsal and lateral directions. The authors observe the predominance of forces that bend the pterygoid process in the medial direction, which influences the increase in thickness of the medial osseous plate. However, the hamulus head is subjected to overloading in the lateral and dorsal directions (Putz and Kroyer 1999). Moreover, taking into account the entire sphenoid bone, it is the medial plate of the pterygoid process that is affected by the biggest overloads. In a juvenile bone the medial plate can withstand the maximum stress of around 57.2 MpPa, in the case of an adult person was 371.1 MPa. The literature contains data on the forces affecting PH in a juvenile which amount to about 0.1 kg/mm2 (Holberg 2005).

The pterygoid hamulus, being an important topographic point and an attachment point of numerous structures, plays a significant role in skull base surgery (Lanetti et al. 1996) as well as a large role in the swallowing mechanism (Takezawa and Kageyama 2012) and in cleft palate plastic surgery (Flores et al. 2010). What is more, the structure of PH may affect the development of pterygoid hamulus bursitis (Gores 1964; Iin-Yong et al. 2013; Ramirez et al. 2006; Sasaki et al. 2001; Sattur et al. 2011; Wooten et al. 1970). In our research we stated that in the archaeological material 30% of the increased width and length of PH was accompanied by an extended styloid process. This may be of importance in the similarity of clinical symptoms of hamulus bursitis and Eagle's syndrome and will be analyzed in later studies (Putz and Kroyer 1999). The PH features may also change due to an anomaly developing in the structure of the soft palate (Kerr and Apte 1975). From the point of view of prosthetics, PH has an impact on the formation of the vibrating line (Iwanga et al. 2017). Despite the high importance of HP, morphometric studies of this structure are very few.

Conclusion

On the basis on the present study, the significance of differences in the studied population was observed in the length of the pterygoid process in correlation with sex and age. The results obtained may explain the predisposition of older people to the development of pterygoid hamulus bursitis. Apart from the difference in the width of PH, no significant differences in its structure in the modern and medieval populations were revealed.

Authors' contributions

IK and HM-P developed the idea for the research, took cranial and Tc measurements, interpreted results and wrote the manuscript; IK was principal investigator in the research project; EU, DDz and MG searched for bibliographic records; BC supervised the research. All authors read and approved the final version submitted.

Conflict of interest

The authors declare that there no conflict of interest regarding publication of this paper.

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