Received: 16.03.2026 | Revision: 28.03.2026 | Accepted: 16.04.2026 | Published: 12.09.2026

Veterinary Sciences

doi: 10.31210/spi2026.29.02.11
UDC 636.1:611.716:340.6

ORIGINAL ARTICLE

Scientific Progress & Innovations 29 (2) 2026

ISSN: 2786-8842 (Print)
2786-8850 (Online)

Methodical approaches to cranioscopic study of purebred Arabian horses in the context of forensic veterinary examination

I. Yatsenko[1,6] | R. S. K. Abuznaid[2] | V. Binkevych[3] | I. Biben[4] | L. Savchuk[5] | V. Dobrovolskyi[5] | N. Kravchenko[6]

Article info

Citation: Yatsenko, I., Abuznaid, R. S. K., Binkevych, V., Biben, I., Savchuk, L., Dobrovolskyi, V., & Kravchenko, N. (2026). Methodical approaches to cranioscopic study of purebred Arabian horses in the context of forensic veterinary examination. *Scientific Progress & Innovations*, 29(2), 70–77. doi: 10.31210/spi2026.29.02.11

Correspondence Author
I. Yatsenko
E-mail:
yacenko–1971@ukr.net

[1] National Scientific Center "Hon. Prof. M. S. Bokarius Forensic Science Institute",
8-a Zolochivska Str., Kharkiv, 61177, Ukraine

[2] Palestine Polytechnic University, Wadi al-Hariya Str., Hebron, P700, Palestine

[3] Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies Lviv,
50 Pekarska Str., Lviv, 79010, Ukraine

[4] Dnipro State Agrarian and Economic University,
25 Serhii Yefremov Str., Dnipro, 49000, Ukraine

[5] Higher education institution "Podilskyi State University", Kamianets-Podilskyi, 12 Shevchenko Str., 32301, Ukraine

[6] State Biotechnological University,
44 Alchevskykh Str., Kharkiv, 61002, Ukraine

The aim of the study is to formulate and substantiate methodological approaches to the osteoscopic examination of the nasocranial part of the skull of purebred Arabian horses in the context of forensic veterinary expertise. The informativeness of osteological examination parameters (osteoscopy) of the nasocranial region of the skull of purebred Arabian horses was analyzed. The study was conducted on 36 dry skulls of purebred Arabian horses obtained from veterinary anatomical collections and verified according to breeding documentation. The skulls were selected based on preservation criteria, which included the absence of postmortem damage, deformation, or pathological changes that could affect morphometric analysis. Cranial reference points were identified and their localization was described. It was established that the skull is an informative material for determining the age and sex of animals and can serve as a basis for the development of computer-based technologies for expert examinations. The skulls were obtained from horses aged from 1 day to 5 years. The age dependence of cranial measurements was determined on 60 skulls of Arabian horses. Thus, the study presents a comprehensive approach to the osteoscopic analysis of the nasomaxillary region of the skull of purebred Arabian horses, emphasizing its practical application in forensic veterinary examination of cranial material. Visual anatomical assessment of horse skulls allows for determining the sex and age of unidentified remains. It is noted that the identified cranial landmarks, particularly those associated with the frontal and nasal bones, demonstrate stable sexual dimorphism and age-related variability, confirming their high diagnostic value in forensic veterinary examinations. The proposed innovative developments will form the basis of standardized protocols aimed at improving the scientific accuracy and efficiency of cranial forensic veterinary investigations, especially for animal identification and estimation of the postmortem interval. The study confirms the growing role of forensic veterinary expertise in the legal and ethical assessment of animal welfare. Further research should focus on expanding applications to other horse breeds and integrating modern imaging methods to enhance the accuracy of expert conclusions.

Keywords: forensic veterinary expertise, purebred Arabian horses, skull, methodology, osteology, craniology, cranioscopy.

Методологічні підходи до краніоскопічного дослідження чистокровних арабських коней у контексті судово-ветеринарної експертизи

І. Яценко[1,6] | Р. С. К. Абузнайд[2] | В. Бінкевич[3] | І. Бібен[4] | Л. Савчук[5] | В. Добровольський[5] | Н. Кравченко[6]

[1] Національний науковий центр «Інститут судових експертиз ім. Засл. професора М. С. Бокаріуса, м. Харків, Україна

[2] Палестинський політехнічний університет, м. Хеврон, Палестина

[3] Львівський національний університет ветеринарної медицини та біотехнологій імені С. З. Гжицького, м. Львів, Україна

[4] Дніпровський державний аграрно-економічний університет, м. Дніпро, Україна

[5] Заклад вищої освіти «Подільський державний університет», м. Кам'янець-Подільський, Україна

[6] Державний біотехнологічний університет, м. Харків, Україна

Метою роботи є формулювання та обґрунтування методологічних підходів до остеоскопічного дослідження носокраніальної частини черепа чистокровних арабських коней у контексті судово-ветеринарної експертизи. Проаналізовано інформативність параметрів остеологічного дослідження (остеоскопії) носокраніального відділу черепа чистокровних арабських коней. Дослідження проведено на 36 сухих черепах чистокровних арабських коней, отриманих із ветеринарно-анатомічних колекцій та верифікованих за племінною документацією. Черепи відбирали за критеріями збереженості, що передбачали відсутність посмертних пошкоджень, деформацій або патологічних змін, які могли б вплинути на морфометричний аналіз. Визначено краніологічні орієнтири та описано їхню локалізацію. Встановлено, що череп є інформативним матеріалом для визначення віку та статі тварин і може бути основою для розроблення комп'ютерних технологій експертних досліджень. Черепи отримано від коней віком від 1 доби до 5 років. Вікову залежність краніологічних вимірів визначено на 60 черепах арабських коней. Отже, дослідження репрезентує комплексний підхід до остеоскопічного аналізу носомозкового відділу черепа чистокровних арабських коней з акцентом на його практичному застосуванні у судово-ветеринарній експертизі краніологічного матеріалу. Візуальна анатомічна оцінка черепа коней дає змогу визначати стать і вік невстановлених решток коней. Звертається увага на те, що виявлені краніологічні орієнтири, зокрема пов'язані з лобовими та носовими кістками, демонструють стабільний статевий диморфізм і вікову мінливість, що підтверджує їхню високу інформативність під час судово-ветеринарних експертиз. Запропоновані інноваційні розробки стануть основою стандартизованих протоколів, спрямованих на підвищення наукової точності та ефективності краніологічних судово-ветеринарних досліджень, особливо для ідентифікації тварин і визначення післясмертного інтервалу. Дослідження підтверджує зростаючу роль судово-ветеринарної експертизи у правовій та етичній оцінці добробуту тварин. Подальші дослідження доцільно спрямувати на розширення застосування до інших порід коней та інтеграцію сучасних методів візуалізації для підвищення точності експертних висновків.

Ключові слова: судово-ветеринарна експертиза, чистокровні арабські коні, череп, методологія, остеологія, краніологія, краніоскопія.

Бібліографічний опис для цитування: *Яценко І., Абузнайд Р. С. К., Бінкевич В., Бібен І., Савчук Л., Добровольський В., Кравченко Н.* Методологічні підходи до краніоскопічного дослідження чистокровних арабських коней у контексті судово-ветеринарної експертизи. *Scientific Progress & Innovations*. 2026. № 29 (2). С. 70–77.

Introduction

Osteology, as a branch of morphology, is an indispensable tool for studying the origin and evolutionary development of animals, understanding their adaptive traits [5]; predicting productivity, diagnosing diseases, evaluating and analyzing the effectiveness of treatment measures; and in forensic veterinary examinations: determining taxonomic classification, identifying the sex and age of animals [2], detecting the presence or absence of pathological changes in the animal's body during life, estimating the time of death or the duration of corpse exposure to environmental conditions [3], identifying fatal injuries [4, 5], as well as hidden injuries [6]; bodily harm, which allows for objective documentation of factual data regarding offenses committed against the health and life of an animal [7, 8, 9]. Moreover, the processes of rearing, processing, and selling livestock products are often accompanied by violations such as product adulteration, poaching, theft, and slaughtering of animals for meat [10, 11, 12]. Therefore, for diagnostic osteological studies, priority should be given to determining the species, sex, and age of slaughtered animals based on their body parts-especially those of low commercial value, such as distal limb segments, the head, tail, etc.-left near the scene of the crime [13, 14].

The skeleton is the most informative structure for diagnostics, allowing for the identification of animal injuries not only in fresh cases of death or slaughter but even after a significant period of time [15]. Thus, solving the issues of determining the age and sex of animals based on skeletal bones is one of the few scientific directions in morphology and forensic veterinary science whose results are applied in determining the characteristics of an animal's body from its individual parts [16].

Forensic veterinary examinations increasingly rely on osteometric and osteoscopic analyses to solve issues related to unidentified animal remains, particularly in cases of decomposed, skeletonized, or dismembered animal corpses [17].

However, there is still a lack of clearly defined and scientifically grounded methodological recommendations, especially regarding productive animals. Therefore, the development of such methodologies should be based not only on certain macroscopic age-related criteria of an animal's skeleton but also on the knowledge of variability in osteometric, radiographic, microstructural, spectroscopic, and other parameters across a broad age and sex range.

Among the variety of biological material, the skull is the most informative for forensic veterinary examination and morphology. The issue of forensic veterinary craniology is a central focus for morphologists and forensic veterinary experts. The method for determining age and sex using craniometric indices in cattle for forensic veterinary purposes was first developed by Abuznaid [18]; the applied anatomy of the Arabian horse's skull was substantiated by Goodarzi et al. [19] and Pompermayer et al. [20]; a pilot study of horse and donkey skulls was demonstrated by Merkies et al. [21]; covariance (modularity) levels between components of the horse skull structure were studied by Parés-Casanova [22]; comparison of the back profiles of donkeys, ponies, and horses, as well as head shapes using geometric morphometry, was illustrated by Maśko et al. [23]; geometric morphometric methods to visualize skull shape differences in horses of different ages were applied by Liuti et al. [24]; 3D cephalometric comparisons using CT scanning between straight-lined Egyptian Arabian and Thoroughbred horses were conducted by Alshami et al. [25] (2024); geometric morphometry of the facial profile of various horse breeds, including Arabians, was discussed by Alhaddad et al. [26]. However, researchers have not only focused on horse skulls. Studies have also investigated the morphological features of skulls in other animal species: Jashari et al. [27] used morphometric analysis to determine the sex of dog skulls; Gündemir et al. [28] established morphometric parameters for skulls of indigenous sheep breeds; Çakar et al. [29] compared morphometric skull characteristics of Simmental and Holstein cattle breeds; Gündemir et al. [30] studied skull shape variations in British Shorthair, Scottish Fold, and Van cats; Vishwakarma et al. [31] established cranial dimensions and sexual dimorphism in the skull bones of the gaur.

Despite the relevance of veterinary craniology, there is a limited number of standardized methods for evaluating skulls of various animal species, including horses-especially in the context of forensic veterinary examinations-since integrating traditional osteological methods with modern morphometric analysis provides a more objective and reproducible approach to identification.

Thus, the study of the skull of purebred Arabian horses in the context of forensic veterinary science holds both theoretical and practical interest, as it aims to develop a detailed methodological basis for craniometric analysis of purebred Arabian horses. By identifying consistent anatomical landmarks and evaluating morphological variations, this research seeks to assist forensic veterinary experts in accurately determining age and sex, thereby enhancing the evidential value of skeletal remains in legal proceedings.

This goal can be achieved through systematic scientific research, the creation of specialized methodological literature, and the development of appropriate computer technologies that would organize, simplify, and automate the processing of osteological research results based on a reference-testing principle.

In light of the above, studying age-related morphological characteristics of the skull – including that of purebred Arabian horses-while considering sex, for the purposes of forensic veterinary examination, based on rational methods of bone structure analysis, the comprehensive application of which in practice would allow for the objective determination of the animal's age, is of scientific and practical relevance.

The aim of the study

The aim of the work is to formulate and substantiate methodological approaches to the osteoscopic and osteometric study of the nasocranial part of the skull of purebred Arabian horses in the context of forensic veterinary examination.

Materials and methods

This study was conducted on a total of 36 dry skulls of purebred Arabian horses, collected from veterinary anatomical collections and verified through breeding records. The skulls were selected based on preservation quality, ensuring the absence of post-mortem damage, deformation, or pathological alterations that could interfere with morphometric analysis.

The osteometric and osteoscopic examination focused on the nasocranial region. Standard osteological landmarks were used to ensure consistency across measurements. Each skull was examined in a standardized position with the infraorbital foramen and facial crest properly aligned to provide reproducible reference planes.

Osteoscopic analysis involved visual inspection for sexually dimorphic traits, asymmetries, and specific breed-related morphological features such as the curvature of the nasal bones and the degree of frontal convexity. Observations were recorded using a structured checklist to ensure objectivity.

Age and sex of the specimens were determined based on available breeding documentation and confirmed by dental eruption and wear patterns where possible. Data were statistically analyzed using descriptive statistics and comparative analysis to assess the significance of metric and morphological differences between sexes and age groups.

All procedures adhered to ethical standards for the use of animal skeletal remains in research, and the study was conducted in accordance with institutional guidelines.

Results and discussion

The osteometric analysis of the nasocranial region in purebred Arabian horse skulls revealed distinct morphological patterns associated with sex and estimated age groups. The data were grouped into two primary categories based on biological sex (male and female) and subdivided into age classes (young: 2–5 years, adult: 6–12 years, senior: >12 years).

1. Osteometric Measurements:

Significant differences were observed in several key cranial dimensions between male and female skulls. On average, males exhibited greater values in:

- Frontal width: Mean = 10.6 cm (males) vs. 9.8 cm (females);
- Nasal length: Mean = 15.2 cm (males) vs. 14.1 cm (females);
- Interorbital distance: Mean = 7.3 cm (males) vs. 6.7 cm (females);

Statistical analysis (t-test) confirmed that these differences were significant ($p<0.05$), particularly in the frontal and nasal measurements. No significant difference was observed in maxillary length between sexes.

2. Osteoscopic Observations:

Visual inspection identified consistent sexual dimorphism in the curvature of the nasal bones and prominence of the supraorbital ridges. Male skulls typically exhibited:

- A broader and more convex frontal bone;
- More robust zygomatic arches;
- Deeper nasal depressions.

Female skulls were generally more gracile, with smoother contours and less pronounced cranial ridges.

3. Age-Related Variations:

Skulls from older horses (>12 years) showed more advanced suture closure, especially at the nasofrontal and interfrontal sutures. Additionally, dental wear patterns corresponded reliably with the age groups, supporting the osteological age estimation.

Overall, the combined use of quantitative and qualitative markers proved effective in distinguishing sex and estimating age from the nasocranial structures of Arabian horse skulls.

Table 1

Osteometric measurements on the dorso-lateral surface of the naso-maxillary region of the Arabian horse skull

Symbols	Measurement Point Name	Explanation
		Cranial Measurement Points
b	Bregma (frontal-parietal suture point)	Located at the junction of the metopic and frontal-parietal sutures in the median plane.
r	Rinion	Located at the anterior end of the nasal bone in the median plane.
n	Nasion	Located at the junction of the metopic and internasal sutures in the median plane.
nl	Lateral point of the nasal bone	Located at the nasomaxillary suture at the midpoint of the nasal bone length.
nm	Medial point of the nasal bone	Located at the internasal suture at the midpoint of the nasal bone length.
min	Incisor-maxillary suture point	Located at the oral end of the incisor-maxillary suture from the lateral surface.
tm	Maxillary tuberosity point	Located at the aboral edge of the maxillary tuberosity.
p	Prosthion	Located at the oral end of the interincisive suture.
r	Rinion	Located at the nasal end of the internasal suture.
tb	Cheek tuberosity point	Located at the apex of the cheek tuberosity.
fl	Frontal-lacrimal point	Located at the lateral end of the frontal-lacrimal suture at the dorsal edge of the ocular orbit.
ov	Orbital ventral point	Located at the intersection of the frontal process of the zygomatic bone and the ventral edge of the ocular orbit.
om	Orbital medial point	Located at the medial corner of the ocular orbit at the area of the lacrimal foramen.
ol	Orbital lateral point	Located at the lateral end of the suture between the zygomatic process of the frontal bone and the frontal process of the zygomatic bone.
		Cranial Parameters
1.	Length of the frontal bone	Distance between the bregma (b) and nasion (n) points.
2.	Length of the nasal bone	Distance between the rinion (r) and nasion (n) points.
3.	Direct width of the nasal bone	Distance between the lateral (nl) and medial (nm) points of the nasal bone.
4.	Incisor-maxillary suture length	Distance between the incisor-maxillary suture point (min) and the maxillary tuberosity point (tm).
5.	Cheek width of the skull	Distance between the left (tb) and right (tb I) cheek tuberosity points.
6.	Length of the nasal cavity entrance	Distance between the prosthion (p) and rinion (r) points.
7.	External orbital height	Distance between the frontal-lacrimal (fl) and orbital ventral (ov) points.
8.	External orbital width	Distance between the orbital medial (om) and orbital lateral (ol) points.

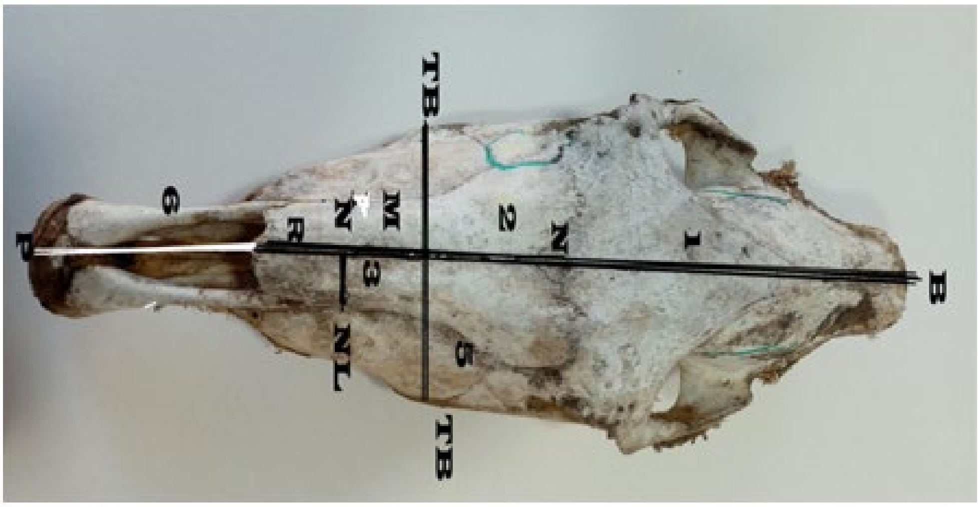

Fig. 1. Craniometric parameters. Dorso-lateral surface of the naso-cerebral region of the skull in the Arabian horse (explanation in the ***table 1***). Macrophotograph: digital camera «Olympus C-5060 Wide Zoom».
Source: developed by the authors of this study

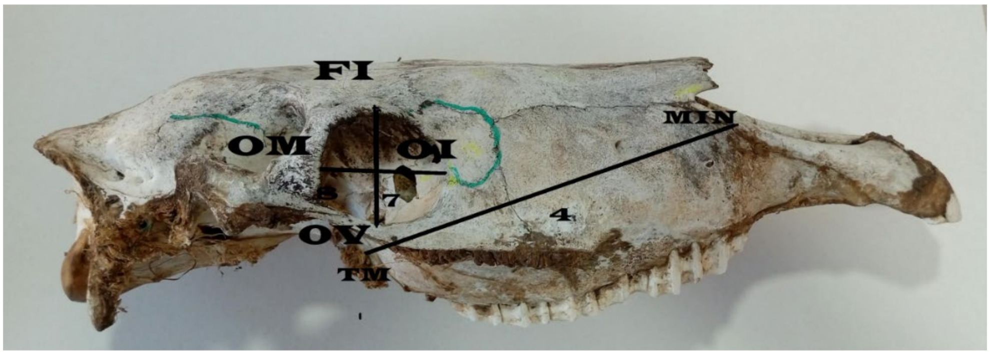

Fig. 2. Craniometric parameters. Lateral surface of the naso-cerebral region of the skull in the Arabian horse (explanation in ***table 1***). Macrophotograph: digital camera "Olympus C-5060 Wide Zoom"
Source: developed by the authors of this study

On the ventral surface of the naso-cerebral region of the skull of the Arabian horse, the following craniological features are identified: hypoglossal foramina, condylar canal, pharyngeal tubercles, oval foramen, choanae, bony palate, anterior (major) palatine foramina, nasopalatine fissures, and incisive fissure.

On the ventral surface of the naso-cerebral region of the Arabian horse skull, we identified 8 osteometric points, based on which 8 craniometric parameters were developed (***Table 2***, ***Fig. 3***).

Table 2
Osteometric measurements on the ventral surface of the naso-cerebral region of the skull of the Arabian horse

Symbols	Measurement Point Name	Explanation
		Cranial Measurement Points
ba	Basion	Located at the lower margin of the foramen magnum in the median plane.
pr	Premolar Rostral Point	Located at the level of the rostral edge of P1 (first premolar) on the medial surface.
ci	Cylindro Point	Located at the apex of the ridge-like thickening of the palatal process of the incisive bone.
os	Occipital-Sphenoidal Point	Located at the junction between the rostral end of the occipital bone body and the aboral end of the sphenoid bone.
gp	Gamuli Pterygoidei Point	Located on the lateral surface of the hamular processes of the pterygoid bone.
st	Staphylion	Located at the aboral edge of the horizontal plate of the palatine bone, in the median plane.
ma	Molar Aboral Point	Located at the level of the aboral edge of M3 (third molar) on the medial surface.
po	Palatine Oral Point	Located on the most prominent part of the oral edge of the palatine bone, in the median plane.
		Cranial Parameters
9	Skull Length	Distance between basion (ba) and prosthion (p).
10	Edentulous Border Length	Distance between premolar rostral point (pr) and cylindro point (ci).
11	Occipital Bone Body Length	Distance between basion (ba) and occipital-sphenoidal point (os) along the median plane.
12	Choanal Length	Distance between occipital-sphenoidal point (os) and staphylion (st).
13	Choanal Width	Distance between left (gp) and right (gpI) gamuli pterygoidei points.
14	Aboral Width of the Hard Palate	Distance between left (ma) and right (ma) molar aboral points.
15	Rostral Width of the Hard Palate	Distance between left (pr) and right (prI) premolar rostral points.
16	Palatine Bone Length	Distance between staphylion (st) and palatine-oral point (po).

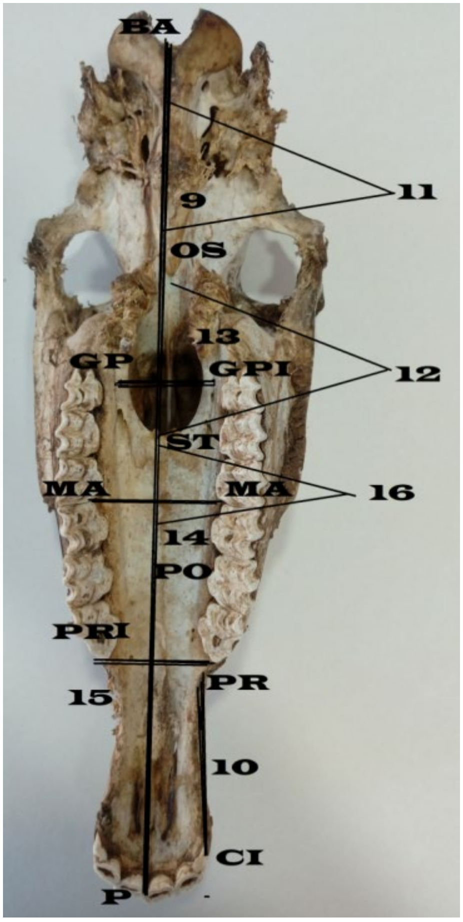

Fig. 3. Craniometric parameters. Ventral surface of the naso-cerebral region of the skull of the Arabian horse. Macrophotograph: digital camera "Olympus C-5060 Wide Zoom" (explanation in ***table 2***).
Source: developed by the authors of this study

The craniological parameters on the occipital surface of the naso-cerebral part of the skull in the Arabian horse include: the temporal crest, the shape of the interparietal bone, the foramen magnum, the occipital condyles, the jugular processes, the nuchal fossa, and the occipital crests. On the occipital surface of the naso-cerebral part of the skull in the Arabian horse, we have identified 10 osteometric points, based on which 7 craniometric parameters were developed (***Table 3***, ***Fig. 4***).

The result of the theoretical-experimental research conducted on the nasal-brain region of the skull generally includes the determination of qualitative craniological parameters and quantitative craniometric parameters (32 craniometric points, based on which 23 measurements were developed). The prospects for further research will involve determining the informativeness of both qualitative and quantitative craniometric parameters for craniological diagnosis of age and sex in Arabian horses.

Summarizing the results of the conducted research, it should be noted that the bones of an animal's skeleton are a valuable means of solving identification, diagnostic, and situational tasks that may arise in forensic veterinary examination. This discipline serves as a method of proving offenses committed against the life and health of animals, including cases of animal cruelty, poaching, and others, while the conclusion of a forensic expert constitutes a source of evidence in court.

Among the biological remains of an animal, its skull has high significance for determining species, sex, age, and past diseases, as it contains numerous informative morphological features.

The findings of this study demonstrate the forensic relevance of both osteometric and osteoscopic parameters in the nasocranial region of purebred Arabian horse skulls [5, 6, 7]. The significant sexual dimorphism observed in frontal width, nasal length, and interorbital distance suggests that these measurements can be reliably used to support biological profiling in forensic veterinary contexts, as confirmed by the scientific studies of Goodarzi et al. [19], Pompermayer et al. [20], and Alshami et al. [25]. These cranial traits not only reflect general sexual differences in equine skeletal morphology but also highlight breed-specific characteristics influenced by selective breeding practices in Arabian horses.

Table 3
Osteometric measurements on the occipital surface of the naso-cerebral part of the skull in the Arabian horse

Symbols	Measurement Point Name	Explanation
		Cranial Measurement Points
ba	Basion	Point located at the lower margin of the foramen magnum in the median plane.
b	Bregma	Junction of the interfrontal and frontotemporal sutures in the median plane.
fti	Frontotemporal Point	Point between the caudal end of the external frontal crest and the upper end of the temporal crest.
t	Temporal Point	Point between the caudal end of the zygomatic process of the temporal bone and the lower temporal crest.
op	Opisthion	Point at the upper margin of the foramen magnum in the median plane.
co	Condylar-Occipital Point	Junction of the lateral end of the upper margin of the foramen magnum and the occipital condyle.
cd	Superior Condylar Point	Highest point of the occipital condyle.
cv	Inferior Condylar Point	Lowest point of the occipital condyle.
cl	Lateral Condylar Point	Most protruding point at mid-length of the lateral edge of the occipital condyle.
cm	Medial Condylar Point	Most protruding point at mid-length of the medial edge of the occipital condyle.
		Craniometrical Parameters
17	Height of Occipital Surface	Distance between bregma (b) and basion (ba).
18	Dorsal Occipital Width	Distance between left (ft) and right (ftI) frontotemporal points.
19	Ventral Occipital Width	Distance between left (t) and right (tI) temporal points.
20	Vertical Diameter of Foramen Magnum	Distance between basion (ba) and opisthion (op).
21	Transverse Diameter of Foramen Magnum	Distance between left (co) and right (coI) condylar-occipital points.
22	Length of Occipital Condyle	Distance between superior (cd) and inferior (cv) condylar points.
23	Width of Occipital Condyle	Distance between lateral (cl) and medial (cm) condylar points.

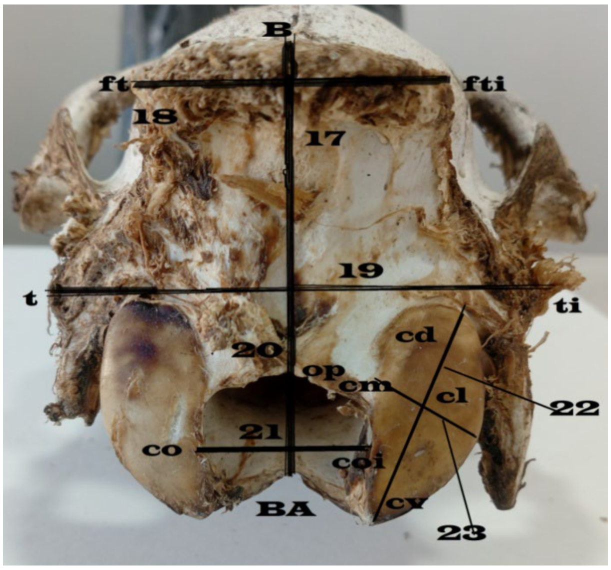

Fig. 4. Craniometric parameters. Occipital surface of the nasomental region of the skull. Macrophoto: Digital camera "Olympus C-5060" wide zoom (explanation in ***table 3***).
Source: developed by the authors of this study

The osteoscopic assessment further complemented the quantitative analysis by identifying visually distinguishable features such as the degree of frontal convexity and the robustness of the zygomatic arches [18, 26]. These observations align with previous research in forensic anthropology and comparative veterinary osteology [18], reinforcing the utility of visual markers in cases where metric analysis may be limited due to fragmentary remains.

The study also revealed age-related changes in cranial suture closure and dental wear, consistent with established veterinary forensic methods for age estimation, as emphasized by Dickey et al. [32], Khazaeel et al. [33], Łuszczyński et al. [34], and Carmalt et al. [35]. The integration of age and sex identification into a unified methodological framework enhances the interpretive value of skeletal remains, particularly in legal investigations involving animal cruelty, neglect, or identity verification, as confirmed by Liu et al. [36], Trbojević et al. [37], and Rannamäe et al. [38].

Despite the robust findings, certain limitations must be acknowledged. The sample size, while representative, remains limited to purebred Arabian horses and may not fully reflect the cranial variation present across other breeds or mixed-breed populations, as highlighted by Sadeghi et al. [39]. Additionally, the use of dry skulls, though ideal for measurement accuracy, does not capture potential soft-tissue influences relevant to live-animal forensic assessments, as supported by the scientific research of Lund et al. [8].

Future research should expand the dataset to include a broader range of breeds and incorporate 3D imaging techniques to refine morphometric protocols, as noted by Kutara et al. [40] and Epperly et al. [41]. Establishing a comprehensive forensic database of equine cranial metrics could serve as a valuable reference for veterinary forensic practitioners worldwide.

Thus, the data of the above-mentioned researchers confirm the results of our study and demonstrate their relevance, prospects, and practical significance in forensic veterinary examination and morphology.

Conclusions

This study establishes a systematic approach for the osteoscopic examination of the nasocranial region in purebred Arabian horse skulls, emphasizing its practical application in forensic veterinary science. The combined use of morphometric data and visual anatomical assessment enables accurate determination of sex and age, offering valuable tools for identifying unknown equine remains.

The identified cranial landmarks, particularly those associated with frontal and nasal bone morphology, exhibit consistent sexual dimorphism and age-related variation, supporting their forensic reliability. These findings contribute to the development of standardized protocols that enhance the scientific rigor of veterinary forensic investigations, particularly in legal contexts involving animal identification and post-mortem analysis.

By providing an evidence-based framework for cranial analysis, this research supports the growing role of veterinary forensic medicine in legal and ethical animal welfare assessments. Further studies are recommended to broaden the scope of application across other equine breeds and to integrate advanced imaging technologies for improved forensic accuracy.

Prospects for further research will be directed toward osteometric, radiographic, and X-ray densitometric studies of skulls of purebred Arabian horses in the context of forensic veterinary examination for the purpose of determining their age and sex.

DECLARATIONS

Ethical Statement

The authors declare that the examination and osteometric analysis of the specimens were conducted in accordance with international ethical norms and veterinary guidelines. Since this study was based exclusively on the evaluation of dry skulls of purebred Arabian horses (*Equus caballus*) obtained from veterinary anatomical collections and did not involve experiments on live animals, harm, or artificial induction of pathological states, formal institutional bioethics committee approval was not required.

Funding
This research received no external funding.

Conflict of Interest
The authors state that there is no conflict of interest. .

Acknowledgements
None.

Declaration of AI and AI-assisted technologies
The author declare that no artificial intelligence or AI-assisted technologies were used in the preparation of this manuscript.

References

1. Hanot, P., Bayarsaikhan, J., Guintard, C., Haruda, A., Mijiddorj, E., Schafberg, R., & Taylor, W. (2021). Cranial shape diversification in horses: variation and covariation patterns under the impact of artificial selection. *BMC Ecology and Evolution*, 21(1), 178. https://doi.org/10.1186/s12862-021-01907-5
2. Fackler, N. P., Donahue, R. P., Bielajew, B. J., Amirhekmat, A., Hu, J. C., Athanasiou, K. A., & Wang, D. (2023). Characterization of the age-related differences in porcine acetabulum and femoral head articular cartilage. *Cartilage*, 16(3), 366–375. https://doi.org/10.1177/19476035231214724
3. Cáceres, J. O., & Sainz de los Terreros, J. Y. (2021). A real-world approach to identifying animal bones and Lower Pleistocene fossils by laser induced breakdown spectroscopy. *Talanta*, 235, 122780. https://doi.org/10.1016/j.talanta.2021.122780
4. Schrock, K., Kerwin, S. C., & Jeffery, N. (2021). Outcomes and complications associated with acute gunshot fractures in cats and dogs. *Veterinary and Comparative Orthopaedics and Traumatology*, 35(03), 205–212. https://doi.org/10.1055/s-0041-1739238
5. Haut, R. C., & Wei, F. (2017). Biomechanical studies on patterns of cranial bone fracture using the immature porcine model. *Journal of Biomechanical Engineering*, 139(2), 021001. https://doi.org/10.1115/1.4034430
6. Macoveciuc, I., Márquez-Grant, N., Horsfall, I., & Zioupos, P. (2017). Sharp and blunt force trauma concealment by thermal alteration in homicides: An in-vitro experiment for methodology and protocol development in forensic anthropological analysis of burnt bones. *Forensic Science International*, 275, 260–271. https://doi.org/10.1016/j.forsciint.2017.03.014
7. Janeczek, M., Makowiecki, D., Rozwadowska, A., & Pasicka, E. (2023). Battle wound as a probable cause of the death of an early medieval horse in Ostrów Lednicki, Poland. *International Journal of Paleopathology*, 40, 70–76. https://doi.org/10.1016/j.ijpp.2023.01.002
8. Lund, J. R., Ketover, H. R., Hetzel, S., Waller, K., & Brounts, S. H. (2021). Computed tomographic assessment of brain tissue disruption and skull damage in equine cadaveric heads caused by various firearm-ammunition combinations applied as potential gunshot methods for euthanasia of horses. *American Journal of Veterinary Research*, 82(1), 28–38. https://doi.org/10.2460/ajvr.82.1.28
9. Ellingham, S., & A. Sandholzer, M. (2019). Determining volumetric shrinkage trends of burnt bone using micro-CT. *Journal of Forensic Sciences*, 65(1), 196–199. https://doi.org/10.1111/1556-4029.14150
10. Cartín-Rojas, A. (2017). Food fraud and adulteration: a challenge for the foresight of Veterinary Services. *Revue Scientifique et Technique de l'OIE*, 36(3), 1015–1024. https://doi.org/10.20506/rst.36.3.2733
11. Anagnostou, M., & Doberstein, B. (2021). Illegal wildlife trade and other organised crime: A scoping review. *Ambio*, 51(7), 1615–1631. https://doi.org/10.1007/s13280-021-01675-y
12. Corlatti, L., Sanz-Aguilar, A., Tavecchia, G., Gugiatti, A., & Pedrotti, L. (2019). Unravelling the sex- and age-specific impact of poaching mortality with multievent modeling. *Frontiers in Zoology*, 16(1), 20. https://doi.org/10.1186/s12983-019-0321-1
13. Yatsenko, I., Tkachuk, S., Pasnichenko, O., Savchuk, L., & Derecha, L. (2022). Informativeness of the microscopic structures of the diaphysis of the metatarsal bones of female cattle for the forensic and veterinary determination of their age. *Scientific Progress & Innovations*, 4, 186–197. https://doi.org/10.31210/visnyk2022.04.23
14. Schmidt, M. J., Steenkamp, G., Failing, K., Caldwell, P., & Kirberger, R. M. (2019). A contribution to age determination of cheetahs (*Acinonyx jubatus*) based on radiographic analysis of the skull and postcranial morphology. *Plos One*, 14(6), e0217999. https://doi.org/10.1371/journal.pone.0217999
15. Yu, K., Wu, H., Shen, C., Li, H., Wei, X., Liu, R., Cai, W., Wang, G., Sun, Q., & Wang, Z. (2021). Identification of antemortem and postmortem fractures in a complex environment by FTIR spectroscopy based on a rabbit tibial fracture self-control model. *International Journal of Legal Medicine*, 135(6), 2385–2394. https://doi.org/10.1007/s00414-021-02633-9
16. Havrylin, P. M., Prokushenkova, O. H., Yatsenko, I. V., Shuleshko, O. O., & Masyuk, D. M. (2012). Sudovo-veterynarne vyznachennia vydu tvaryn za okremymy frahmentamy tila [Forensic veterinary determination of animal species based on individual body fragments]. *Problemy Zooorhanizatsii ta Veterynarinoi Medytsyny*, 24(2), 426–430. (in Ukrainian)
17. Jaworski, K., Pankiewicz, A., Chrószcz, A., & Poradowski, D. (2020). Different approach to horses – the use of equid remains in the early Middle Ages, on the example of ostrów Tumski in Wroclaw. *Animals*, 10(12), 2294. https://doi.org/10.3390/ani10122294
18. Abuznaid, K. R. S. (2015). Vyznachennia viku ta stati za kraniometrychnymy pokaznykamy velykoi rohatoi hudoby pry sudovo-veterynarnii ekspertyzi [Determination of age and sex based on craniometric indices of cattle in forensic veterinary examination]. *Problemy Zooinzhenerii ta Veterynarnoi Medytsyny: Zbirnyk Naukovykh Prats Kharkivskoi Derzhavnoi Zooveterynarnoi Akademii*, 31(2), 226–234. (in Ukrainian)
19. Goodarzi, N., Zehtabvar, O., & Tohidifar, M. (2021). Applied anatomy of the skull in the Arabian horse: A computed tomographic, cross-sectional, volumetric and morphometric study. *Veterinary Medicine and Science*, 7(6), 2225–2233. https://doi.org/10.1002/vms3.618
20. Pompermayer, E., Hoey, S., Ryan, J., David, F., & Johnson, J. P. (2023). Straight Egyptian Arabian skull morphology presents unique surgical challenges compared to the Thoroughbred: a computed tomography morphometric anatomical study. *American Journal of Veterinary Research*, 84(5), 1–7. https://doi.org/10.2460/ajvr.22.11.0191
21. Merkies, K., Paraschou, G., & McGreevy, P. D. (2020). Morphometric characteristics of the skull in horses and donkeys – A pilot study. *Animals*, 10(6), 1002. https://doi.org/10.3390/ani10061002
22. Parés-Casanova, P. M. (2021). No modularity at ventral level in the horse skull. *Anatomia, Histologia, Embryologia*, 50(5), 849–852. Portico. https://doi.org/10.1111/ahe.12728
23. Maśko, M., Wierzbicka, M., Zdrojkowski, Ł., Jasiński, T., Sikorska, U., Pawliński, B., & Domino, M. (2022). Comparison of donkey, pony, and horse dorsal profiles and head shapes using geometric morphometrics. *Animals*, 12(7), 931. https://doi.org/10.3390/ani12070931
24. Liuti, T., & Dixon, P. M. (2020). The use of the geometric morphometric method to illustrate shape difference in the skulls of different-aged horses. *Veterinary Research Communications*, 44(3-4), 137–145. https://doi.org/10.1007/s11259-020-09779-8
25. Alshami, A. M., Pompermayer, E., Troteaga Alvarez, C., Hoey, S., Ryan, J., & Johnson, J. P. (2023). Comparison of computed tomography assisted 3D cephalometric measurements in straight egyptian arabian and thoroughbred horses. *Journal of Veterinary Dentistry*, 41(1), 43–48. https://doi.org/10.1177/08987564231203918

26. Alhaddad, H., Powell, B. B., Pinto, L. D., Sutter, N., Brooks, S. A., & Alhajeri, B. H. (2024). Geometric morphometrics of face profile across horse breeds and within Arabian horses. *Journal of Equine Veterinary Science*, 132, 104980. https://doi.org/10.1016/j.jevs.2023.104980
27. Jashari, T., Kahvecioğlu, O., Duro, S., & Gündemir, O. (2022). Morphometric analysis for the sex determination of the skull of the Deltari Ilir dog (*Canis lupus familiaris*) of Kosovo. *Anatomia, Histologia, Embryologia*, 51(4), 443–451. https://doi.org/10.1111/ahe.12807
28. Gündemir, O., Duro, S., Jashari, T., Kahvecioğlu, O., Demircioğlu, İ., & Mehmeti, H. (2020). A study on morphology and morphometric parameters on skull of the Bardhoka autochthonous sheep breed in Kosovo. *Anatomia, Histologia, Embryologia*, 49(3), 365–371. https://doi.org/10.1111/ahe.12538
29. Çakar, B., Tandir, F., Güzel, B. C., Bakıcı, C., Ünal, B., Duro, S., Szara, T., Spataru, C., Spataru, M.-C., & Gündemir, O. (2024). Comparison of skull morphometric characteristics of Simmental and Holstein cattle breeds. *Animals*, 14(14), 2085. https://doi.org/10.3390/ani14142085
30. Gündemir, O., Szara, T., Yalin, E. E., Karabagli, M., Mutlu, Z., Yilmaz, O., Büyükünal, S. K., Blagojevic, M., & Parés-Casanova, P. M. (2023). Examination of shape variation of the skull in British Shorthair, Scottish Fold, and van cats. *Animals*, 13(4), 614. https://doi.org/10.3390/ani13040614
31. Vishwakarma, R., Sharma, C. P., Mondol, S., Habib, B., Bhandari, B., Mishra, R., Gupta, N., Chauhan, J. S., & Nigam, P. (2024). Preliminary study on cranial measurements and sexual dimorphism in skull bones of gaur (*Bos gaurus gaurus*, Smith 1827). *Anatomia, Histologia, Embryologia*, 53(3), e13031. https://doi.org/10.1111/ahe.13031
32. Dickey, J. P., Carmalt, J. L., & Reiswig, J. D. (2022). A retrospective observational cohort study on the expiration of maxillary cheek teeth infundibula in 217 horses. *Journal of Veterinary Dentistry*, 40(1), 12–18. https://doi.org/10.1177/08987564221128116
33. Khazaeel, K., Pesarakli, H., Mashhadi, A. G., & Borujeni, M. P. (2021). Age estimation of Arabian mares by incisors morphometry and dentition changes. *Veterinary Research Communications*, 46(2), 405–417. https://doi.org/10.1007/s11259-021-09865-5
34. Łuszczyński, J., Pieszka, M., Petrych, W., & Stefaniuk-Szmukier, M. (2019). The frequency of errors in determining age based on selected features of the incisors of Icelandic horses. *Animals*, 9(6), 298. https://doi.org/10.3390/ani9060298
35. Carmalt, J. L., Henderson, K. V., Rawlinson, J. E., & Waldner, C. L. (2018). Use of crown height of the maxillary first molar tooth to approximate the age of horses. *American Journal of Veterinary Research*, 79(8), 867–873. https://doi.org/10.2460/ajvr.79.8.867
36. Liu, X., Seguin-Orlando, A., Chauvey, L., Tressières, G., Schiavinato, S., Tonasso-Calvière, L., Aury, J.-M., Perdereau, A., Wagner, S., Clavel, P., Estrada, O., Pan, J., Ma, Y., Enk, J., Devault, A., Klunk, J., Lepetz, S., Clavel, B., Jiang, L., Wincker, P., Collin, Y. R. H., Sarkissian, C. D., & Orlando, L. (2023). DNA methylation-based profiling of horse archaeological remains for age-at-death and castration. *iScience*, 26(3), 106144. https://doi.org/10.1016/j.isci.2023.106144
37. Trbojević Vukičević, T., Korpes, K., Đuras, M., Vrbanac, Z., Javor, A., & Kolenc, M. (2023). Paleopathological changes in animal bones from Croatian archaeological sites from prehistory to new modern period. *Veterinary Sciences*, 10(5), 361. https://doi.org/10.3390/vetsci10050361
38. Rannamäe, E., Andrianov, V., Järv, E., Semjonov, A., Haak, A., & Kreem, J. (2019). A month in a horse's life: healing process of a fractured third metatarsal bone from medieval Viljandi, Estonia. *International Journal of Paleopathology*, 24, 286–292. https://doi.org/10.1016/j.ijpp.2018.07.003
39. Sadeghi, R., Moradi-Shahrbabak, M., Miraei Ashtiani, S. R., Schlamp, F., Cosgrove, E. J., & Antczak, D. F. (2018). Genetic diversity of Persian Arabian horses and their relationship to other native Iranian horse breeds. *Journal of Heredity*, 110(2), 173–182. https://doi.org/10.1093/jhered/esy061
40. Kutara, K., Ono, T., Hisaeda, K., Inoue, Y., Henmi, C., Sho, K., Ohnishi, A., Ohzawa, E., Une, Y., Iwata, E., Shibano, K., Asanuma, T., & Kitagawa, H. (2022). An anatomical study of the skull, the dorsal and ventral nasal conchal bullae and paranasal sinuses in normal Noma horses: Computed tomographic anatomical and morphometric findings. *Anatomia, Histologia, Embryologia*, 51(5), 624–632. https://doi.org/10.1111/ahe.12837
41. Epperly, E., & Whitty, J. A. (2020). Equine imaging. *Veterinary Clinics of North America: Equine Practice*, 36(3), 527–543. https://doi.org/10.1016/j.cveq.2020.08.007

ORCID

I. Yatsenko	https://orcid.org/0000-0001-8903-2129
R. S. K. Abuznaid	https://orcid.org/0009-0007-0792-5275
V. Binkevych	https://orcid.org/0009-0001-6234-7814
I. Biben	https://orcid.org/0000-0002-5580-5135
L. Savchuk	https://orcid.org/0000-0002-6042-8362
V. Dobrovolskyi	https://orcid.org/0000-0002-2678-5649
N. Kravchenko	https://orcid.org/0000-0002-3868-3551