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Original Research Article

Morphometric Analysis of Accessory Vessel Grooves on the Frontal Bone: First Documented Cases from Namibia

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ABSTRACT

This paper presents the first documented cases of accessory vessel grooves on the external cranial vault from Namibia. These nonmetric anatomical variants were observed on two dry skulls housed at the Namibian Police Forensic Science Institute in Windhoek. A morphometric analysis was conducted to document the precise location and measurements of these grooves relative to established cranial osteological landmarks. Accurate identification of such traits is critical in distinguishing normal anatomical variation from cranial trauma, pathological lesions, or taphonomic damage during forensic analysis. This study contributes to the limited literature on cranial vascular imprint variation in African skeletal samples and highlights the need for further research on the morphometric characterization of accessory vessel grooves in forensic and bioarchaeological contents.

KEYWORDS: Accessory vessel grooves, Frontal bone, Nonmetric trait, Forensic anthropology, Supraorbital artery, Namibia.

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INTRODUCTION

Frontal vessel grooves, also known as accessory vessel grooves or accessory vessel sulci, refer to grooves observed in the lateral frontal region of the skull, on the external cranial vault. These grooves are considered nonmetric anatomical features, epigenetic in origin, and are rare anatomical variations [1]. They present as shallow impressions or channels found on the external surface and are located superolateral to the orbits on the frontal bone. These grooves are believed to result from the pulsations of the deep pericranial branches of the supraorbital artery (SoA) [2].

Understanding non-metric traits and minor anatomical variants is crucial for distinguishing normal anatomical features from trauma or pathology, particularly when addressing antemortem, perimortem, and postmortem injuries or damage to bone [2]. While the vessel grooves on the frontal and parietal bones have been documented in literature [1,3,4], the primary objective of this study was to accurately define the dimension, location, and significance of the accessory vessel grooves in the present two case studies. By doing so, we aimed to enhance the understanding of this anatomical variation and its anatomical significance. The cases reported here thus highlight the significance of accessory vessel grooves, particularly their implications for clinical and aesthetic interventions. Furthermore, it highlights the potential of these grooves to be misinterpreted as trauma or pathology by anthropologists and forensic scientists.

METHODS

Two dry skulls with accessory vessel grooves (AVG), subject to this study, were extracted from a sample of skeletal remains housed at the Namibian Police Forensic Science Institute (NPFSI) in Windhoek, Namibia. Ethical approval was obtained from the Ministry of Health and Social Services of Namibia (22/4/2/3) and the Decentralised Ethics Committee of the University of Namibia (SOM16/2023). The variation in AVG on the two skulls were analysed using morphometric measurements and photographic documentation. Both sides of the frontal bone of each skull were visually assessed, and the presence of AVG in relation to the supraorbital foramen or notch was recorded. To evaluate the location and characteristics of the AVG, the number, dimensions, and lengths of the grooves were measured with a digital sliding calliper (R.S. battery metric calliper 0-150mm±0.1mm) to the nearest 0.01mm.

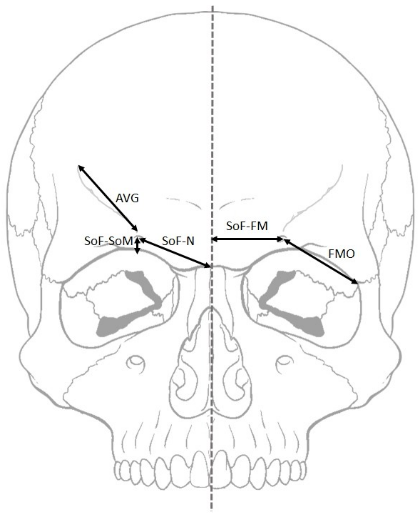

Fig. 1: Norma frontalis with the specific landmarks and associated metrics in reference to the two cases (AVG- accessory vessel groove, SoF/N-FMO- supraorbital foramen/notch to frontomalare orbitale, SoF/N-FM- supraorbital foramen/notch to facial midline, SoF/N-N- supraorbital foramen/notch to nasion, SoF/N-SoM- supraorbital foramen/notch to supraorbital margin).

Morphometric analysis also included measurements of distances between the supraorbital foramen/notch (SoF/N) from several anatomical landmarks, including the supraorbital margin (SoM), nasion (N), facial midline (FM), frontomaxillary orbitale (FMO), and the vertical diameter of the supraorbital foramen or supraorbital notch when present. Additionally, the vertical distance (width) between the supraorbital foramen and notches was also measured (Fig. 1) [5-8].

RESULTS

During the evaluation of skeletal remains (n=20) at the NPFSI, two skulls with AVG were discovered. The ambiguity of this rare phenomenon prompted further investigation, as erroneous conclusions of trauma could have occurred otherwise. Two adult skulls presented with AVGs. This is the first case with the allocated study number. NHB-017 included a skull and three rib fragments of an unknown individual. This individual was a young adult female, aged between 18 and 30 years at the time of death. It was evident that the skull had not been buried, but rather exposed to prolonged direct sunlight and dry seasonal weathering. As a result, stage one weathering was evident, with bleaching and mosaic cracking clearly visible on the exterior surfaces of the skull bones (Figure 2A, B, and C). On both sides of the frontal bone, above the supra-orbital margins of the orbits, are well-defined longitudinal grooves. These grooves originate superiorly to the supra-orbital margins and are associated with left and right accessory supraorbital foramina, and not supraorbital foramina. The grooves are located bilaterally high above both orbits on the superolateral plate of the frontal bone.

On the left, the supra-orbital foramen is duplicated (Figure 2A), forming two small supraorbital foramina situated 3.05mm above the supraorbital margin, 38.30mm from the midline, 40.67mm from the nasion, 21.41mm from the frontomalare orbitale (FMO), and 70.63mm from the right supraorbital foramen. No vessel grooves emanate from these two foramina.

A single main prominent sulcus originates from an accessory supraorbital foramen with a diameter of 1.72mm, lies 11.10mm above the supraorbital margin, 43.30mm from the midline, 49.41mm from the nasion, and 29.68mm from the FMO (Table 1). This well-marked groove with a length of 29.50mm follows a quite linear course before branching into three smaller sub-grooves that extend another 33.54mm obliquely toward the coronal suture. None of these grooves crossed the superior temporal line or coronal suture on the left and right (Figure 2B and C).

On the right half of the frontal bone, a single supraorbital foramen is positioned 5.85mm above the supraorbital margin (SoM), 32.33mm from the midline, 35.72mm from the nasion (N), and 23.77mm from the frontomalare orbitale (FMO), and as already indicated 70.63mm from the left supra-orbital foramen or notch (SoF/N). No visible grooves emanate from this foramen (Figure 2B). The right outer supraorbital surface of the frontal bone shows a series of thin tunnel-like grooves becoming superficial from different accessory foramina. These grooves commence 42.25mm vertically upwards before angling slightly medially toward the coronal suture.

Fig. 2. A: Anterior view of the skull showing bilateral Accessory Vessel Grooves (AVG) and bilateral supraorbital foramina (arrows). **B:** Accessory Vessel grooves (circled) and accessory supraorbital foramina (arrow) on the right side of the skull and double supraorbital foramina on the left (circled). **C:** lateral view of the skull showing the branched Accessory Vessel Grooves (circle) originating from an accessory supra-orbital foramen (arrow). Although the lengths of AVG differ on the left and right frontal bone, it is evident that there is no difference in direction. The vascular grooves on both sides exhibited not only variations in length but also in depth.

The second case, NHB-018, was an incomplete set of skeletal remains. Biological profiling of the remains suggests that the skeletal remains belonged to an adult male, between 35 and 45 years old at the time of death. Superolateral on the left and right of the frontal bone are linear longitudinal accessory vessel grooves (AVG) visible, originating superior to the supraorbital margins of the orbits (Figure 3A, B, and C). Although the lengths of the AVG differ in the right and left frontal bone, there is also no difference in direction. A broad supraorbital notch (SON) is evident, piercing the right supraorbital margin. No supraorbital notch nor a supraorbital foramen were visible on the left supraorbital area. Only a faint and shallow groove marking on the rim was present (Figure 3A).

Fig. 3. A: Anterior view of skull showing bilateral Accessory Vessel Grooves (circles), right supraorbital notch (arrow). **B:** A faint, shallow marking on the left which demarks the AVG (circled). **C:** AVG on the left side of the skull (circled).

The right supraorbital notch, measuring 4.18mm in diameter, is located 23.50mm from midline, 24.05 mm from the nasion, and 20.08mm from the frontomaxillary orbitale (FMO) (Figure 3B). A faint, almost impercep-tible groove crosses the right supraorbital area, originating from the supraorbital notch and extending 66.90mm across the superolateral surface of the frontal bone (Table 1). The lower end of the groove appears to constrict the supra-ciliary ridge just superior to the notch (Figure 3B).

Although no supraorbital foramen or supra-orbital notch is present on the left supraor-bital area, a faint, shallow marking is detected crossing the supraorbital rim, indicating the passage of the supraorbital neurovascular bundle (Fig. 3A). This faint shallow marking is located 24.53mm from the midline, 27.97mm from the nasion, and 20,95mm from the frontomalare orbitale (FMO). The marking has a jagged appearance, resembling a fracture, commencing 21.33mm superolateral on the frontal bone, where it branches in three long, faint, almost linear sub-grooves extending another 51.78mm toward the coronal suture (Figure 3C and Table 1):

Table 1: Osteometrics associated with the two cases.

Parameter (mm)	NHB-017		NHB-018	
	L	R	L	R
AVG	63.04	42.25	73.11	66.9
SoF/N-FMO	21.41	23.77	20.95	20.08
SoF/N-FM	38.3	32.33	24.53	23.5
SoF/N-N	40.67	35.72	27.97	24.05
SoF/N-SoM	3.05	5.58	0	0

AVG- accessory vessel groove, SoF/N-FMO- Supraorbital foramen/notch to frontomalare orbitale, SoF/N-FM- supraorbital foramen/notch to facial midline, SoF/N-N- supraorbital foramen/notch to nasion, SoF/N-SoM- supraorbital foramen/notch to supraorbital margin.

DISCUSSION

Accessory vessel grooves have been identified in two of 20 cases at the NPFSI at the time of investigation. These are the first documented cases related to the Namibian population. In dry skulls, AVG may resemble incision scars, potentially which leading to the misinterpretation that they were caused by sharp force trauma to the frontal bone [1]. Whether in forensic cases or other analyses of human remains, familiarity with the epigenetic variations and typical locations of AVG is essential to differentiate them from skeletal trauma, pathological changes or taphonomic alterations [2].

AVG, though a minor anatomical variant, has been documented in the literature [1-3].

However, the nomenclature and possible anatomical origin of this trait varies. For instance, they are referred to *as supraorbital grooves [9], vascular grooves [4], accessory vascular grooves [1], arterial grooves [10], frontal grooves [11,12], accessory frontal grooves* [2], and *supraorbital nerve grooves* [3,11]. The origin of this trait has therefore been ascribed to either the vessels or nerves.

The aetiology of this phenomenon remains a point of controversy in the literature [13]. The most likely explanation is that, during development, the cranial vault bones form through intramembranous ossification, whereas the bones of the skull base develop through endochondral ossification [13]. The bones enclosing the brain have large, flexible fibrous joints (sutures) that allow the head to pass through the birth canal and allow postnatal brain growth. Human skull ossification continues postnatally until the mid-twenties, and in old age, the sutures are typically completely ossified (obliterated) [13]. With reference to the frontal bone, the marked development of grooves is probably associated with the relatively rapid increase in size of the anterior part of the skull, which takes place between 15 and 25 years of age [3]. The supraorbital cardiovascular bundle might be viewed as constricting cords and has not been in proportion to the expansion of the frontal bone, which then tends to become buried in the developing frontal bone [3]. The foramina face upwards towards the coronal suture, where growth is most active.

The SoA originates from the ophthalmic artery to the superomedial aspect of the orbit [14]. It exits the superior edge of the orbit passing the supraorbital foramen/notch/groove to emerge superior onto the forehead, where it divides into superficial (medial) and deep (lateral) branches, which supply the medial and lateral aspects of the forehead, respectively, extending as far as the coronal suture. The superficial division passes over the frontalis muscle and divides into multiple smaller branches with cephalic distribution toward the hairline. The deep (lateral) division runs deep in the frontalis muscle across the lateral forehead between the epicranial aponeurosis and the pericranium to supply the periosteum of the frontal bone [6]. The supraorbital artery is accompanied by the supraorbital nerve, a continuation of the frontal nerve, which is one of the branches of the ophthalmic division of the trigeminal nerve. The variable anatomy of the SoA and SoN has important neurosurgical considerations regarding different approaches and bypasses [5,8,14].

The supraorbital margin is formed entirely by the frontal bone. This margin is interrupted at the junction of its sharp lateral two-thirds and rounded medial one-third by the supraorbital foramen (SoF) or supra-orbital notch (SoN) [14]. The supraorbital arteries, nerve, and veins emerging from these points form noticeable grooves or sulci across the frontal bone, which can be unilateral or bilateral [3].

These vascular grooves exhibited not only variations in length but also in depth; they could be single but frequently multiple, parallel, or branched [4]. The exit points of the supraorbital nerve, artery, and vein, along with their branches, are of critical importance in medical procedures, including supraorbital endoscopic surgeries, forehead and facial aesthetic plastic surgeries, medical aesthetic applications, and maxillofacial surgeries [2,6-8,15].

Although skull fractures are generally diagnosed with ease by CT scans, various anatomical variants (such as vascular impressions including frontal AVG) can mimic skull fractures in clinical settings [2]. In some cases, distinguishing between a frontal skull fracture caused by trauma and an accessory vessel groove in a living person may be challenging [16].

A thorough understanding of the anatomical configuration of supraorbital vascular grooves is crucial for accurate surgical navigation and clinical diagnosis, particularly in cases involving facial trauma or vascular conditions [6,7,16,17].

Without adequate knowledge of AVG formation, forensic scientists may also misinterpret this anatomical variation as traumatic lesions or pathological findings. The bilateral presence of grooves can aid in distinguishing them from fractures, as their course is usually symmetrical on both sides of the skull. Familiarity with the usual position, location, and anatomical features of these groove impressions when unilateral is essential to differentiate them from linear skull fractures [2,4].

There is limited information about the age of occurrence of accessory vessel grooves [1]. According to Dixon (1904), these grooves are more common in individuals aged 15-30 years, as the frontal part of the skull develops more rapidly during this period. Additionally, Dixon noted that the grooves tend to deepen in individuals aged 40-80 years [3]. Notably, Çirak et al. (2021) also found no significant difference in the presence of AVG between sexes [1].

CONCLUSION

The current report presents two case studies featuring vascular grooves in the frontal bone that may resemble skull trauma. It is evident that the bilateral indentations on the frontal bone in these two cases are arterial vessel grooves (AVG) and not related to trauma, pathology or taphonomy. Recognizing their usual characteristics - such as branching patterns, parallel grooves, occasional bilateralism, and typical locations in the frontal supraorbital regions – helps to differentiate them from trauma or pathology [11].

The current study contributes to the limited existing literature on the epigenetic variation of AVG [1-3], enhancing the understanding of the anatomical features of the supraorbital region. Awareness of AVG location, when present, is valuable for clinicians to prevent misinterpretation as cranial fractures or trauma, whether antemortem or postmortem [2]. This knowledge is also beneficial for anthropologists and forensic scientists [1,2].

Additionally, variations of accessory supraorbital foramina can also lead to misdiagnosis on medical imaging and potentially lead to intraoperative complications [18]. Understanding the possible location of supraorbital structures is crucial, particularly in procedures like supraorbital nerve blocks, commonly used to treat migraine headaches [17]. A comprehensive knowledge of the neurovascular and osseous anatomy surrounding the orbit is essential for selecting and performing the most appropriate orbital approach in each clinical case [6,8]. It is believed that the cases presented will further build on the paucity in the literature on accessory vascular grooves.

ABBREVIATIONS

AVG – Accessory Vessel Grooves
CT – Computed Tomography
FM – Facial Midline, **N –** Nasion
FMO – Frontomalare Orbitale
NPFSI – Namibian police forensic science institute
SoA – Supraorbital Artery,**SoF –** Supraorbital Foramen
SoF/N– Supraorbital Foramen/Notch
SoN – Supraorbital Notch,**SoM –** Supraorbital Margin
SOM – School of Medicine

Conflicts of Interests: The authors declare no competing interests.

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Author Contributions

JvdM and AP contributed to the data collection and analysis, literature search, and manuscript editing.

QW contributed to the design and editing of images and manuscript preparation.

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