



## Gross and morphometrical studies on the bony palate of the domestic pig (*Sus scrofa domestica*)<sup>#</sup>

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### Abstract

The bony palate of the domestic pig was formed rostrally by the bodies and palatine processes of the incisive bones, at the middle by the palatine processes of the maxillae and caudally by the horizontal parts of the palatine bones. The palatine process of the maxillae fused with its fellow along the midline and constituted the major portion of the bony palate. The total length of the bony palate was  $20.8 \pm 1$  cm and the maximum width, observed just behind the canine tooth level, was  $6.7 \pm 0.5$  cm. The palatine fissures were elongated and oval in shape and were located in the rostral part of the bony palate. An oval-shaped major palatine foramen was present on either side of the mid-palatine suture in the caudal part of the palatine process of the maxilla near its junction with the horizontal part of the palatine bone at the level of the junction between the last two upper molar teeth. The distance between the two major palatine foramina was  $2.3 \pm 0.4$  cm. An eminentia canina forming a projection for the canine tooth was observed on the cranial portion of the alveolar processes of the maxilla. Oblique ridges were present on either side of the mid palatine suture on the horizontal part of the palatine bone. At the level of third molar tooth, two to three oval-shaped minor palatine foramina were observed on either side of the mid-palatine suture near the palatomaxillary suture. The mean palatine index was  $32.3 \pm 1.2$  %.

**Keywords:** Bony palate, palatine fissures, domestic pig.

Pigs are widely used as experimental models for studies on various organ systems, including the cardiovascular, renal, gastrointestinal, dermatological, dental and musculo-skeletal systems, as well as for surgical training and xenotransplantation research (Lunney, 2007; Swindle et al., 2012). Anatomically and physiologically, the heart, circulatory system and alimentary tract of pig as well as dietary habits and dental arrangement, closely resemble those of humans (Bustad, 1966). Owing to the comparable rates of maxillary bone regeneration in pigs and humans, pigs serve as suitable experimental models for cleft palate research, which is one of the most common congenital defects in humans. Such models contribute to the development of corrective therapeutic strategies and to the understanding of post-surgical healing mechanisms (Govern et al., 2018). The literature available on the gross morphology and morphometry of the bony palate in domestic pigs is scanty. Hence, the present study was undertaken to study the gross anatomical and morphometrical features of the bony palate in the domestic pig (*Sus scrofa domestica*).

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## Materials and methods

For gross and morphometrical studies of the bony palate, heads from 12 adult domestic pigs of the SVVU-T-17 breed were collected immediately after slaughter from AICRP (All India Coordinated Research Project) on Pigs, SVVU, Tirupati. The research protocol was approved by Institutional Animal Ethics Committee (IAEC) vide Ref. No. 281/go/ReBi/S/2000/CPCSEA/CVSc/TPTY/001/Veterinary Anatomy/2023 dated 08.05.2023. The collected heads were subjected to biological maceration for the removal of soft tissues. The specimens were placed in containers filled with normal water and kept for 3–4 weeks in a well-ventilated environment accessible to flies. Microbial activity initiated soft tissue decomposition, while dipteran larvae facilitated further removal of soft tissues. After complete maceration, the skulls were removed, thoroughly cleaned to eliminate residual debris and dried adequately under sunlight (Sullivan & Romney, 1999; Oliveira, 2018). The cleaned skulls were then utilized for gross and morphometrical studies of the bony palate. Gross observations of the bony palate were recorded. For morphometrical analysis, parameters including length and width of the bony palate, length of the palatine process of the incisive bone, length of the palatine process of the maxilla, length of the horizontal part of the palatine bone, length of the mid-palatine suture, length of the incisive fissure, length and width of the palatine fissure and distance between the two major palatine foramina were measured using a measuring scale, nylon thread and vernier callipers, wherever appropriate. In addition, the palatine index was calculated in the present study. The palatine index was expressed as the percentage ratio of palatine width to palatine length using the following formula: Palatine index (%) = (Palatine width / Palatine length) × 100. The palatine width was measured at the widest part of the bony palate, i.e., just behind the level of the canine teeth. The palatine length was measured along the midline from the rostral end of the palatine process of the incisive bone to the posterior border of the bony palate. All recorded morphometrical data were subjected to statistical analysis (Snedecor & Cochran, 1994) using SPSS software version 17 and the results were expressed as Mean ± SE.

## Results and discussion

In the present study, the bony palate of the domestic pig was formed rostrally by the bodies and palatine processes of the incisive bones, at the middle by the palatine processes of the maxillae and caudally by the horizontal parts of the palatine bones (Fig. 1) as reported in equines (Hillmann, 1975), pigs (Hillmann & Sisson, 1975), ox, buffalo and yak (Gupta et al., 1990), dogs (Evans & De Lahunta, 2012) and in rabbits (Mahdy & Mohammed, 2021). The palatine processes of the maxilla fused along the midline and constituted the major portion of the bony palate (Fig. 1) as reported by Hillmann and Sisson (1975)

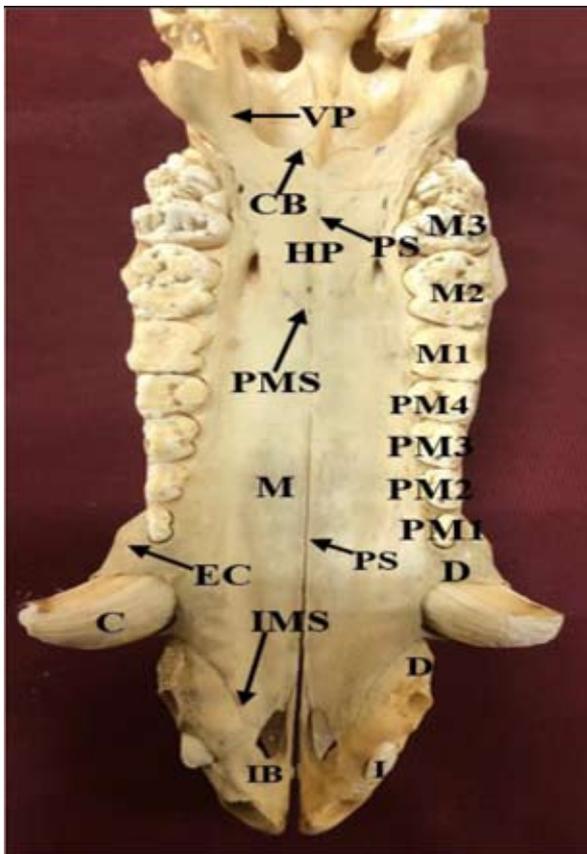
in pigs. Contrary to this finding, Sarma et al. (2001) reported that the palatine bone constituted the major portion of the bony palate in leopard cats, while in rabbits the palatine processes of the incisive bones formed the most predominant portion of the bony palate (Mahdy & Mohammed, 2021).

The bony palate was bounded laterally and rostrally by the alveolar arches of the maxilla and incisive bones, which concurs with the findings of Hillmann (1975) in equines, Hillmann and Sisson (1975) in pigs. The caudal limit of the bony palate extended 1.5 to 2 cm beyond the last cheek tooth level. In contrast to this finding, the caudal limit of the bony palate in ox and yak was at the level of the last cheek tooth, while in buffalo, only its central part extended 3.9 cm beyond the last cheek tooth level (Gupta et al., 1990). The bony palate was narrow rostrally towards the incisor teeth, but it widened at the canine tooth level and narrowed caudally from premolar to molar teeth level (Fig. 1) which was in agreement with the findings reported by Hillmann and Sisson (1975) in pigs and Doley et al. (2018) in wild boars. Contrary to this, in ox, yak and buffalo the bony palate was reported to be wider at both ends with a constricted middle region (Gupta et al., 1990).

In the present study, the total length of the bony palate measured along the midline, from the rostral end of palatine process of incisive bone to the posterior border of bony palate (posterior nares) was  $20.8 \pm 1$  cm, while in local Mizo pigs it was  $15.47 \pm 0.04$  cm (Choudhary et al., 2019),  $4.099 \pm 0.824$  cm and  $6.01 \pm 0.04$  cm in Ghanaian local dogs (Opoku-Agyemang et al., 2020) and in Mizoram goats (Choudhary et al., 2020) respectively. The length of mid-palatine suture measured along the midline from the

**Table 1.** Showing the width of bony palate at different levels in domestic pig (*Sus scrofa domestica*)

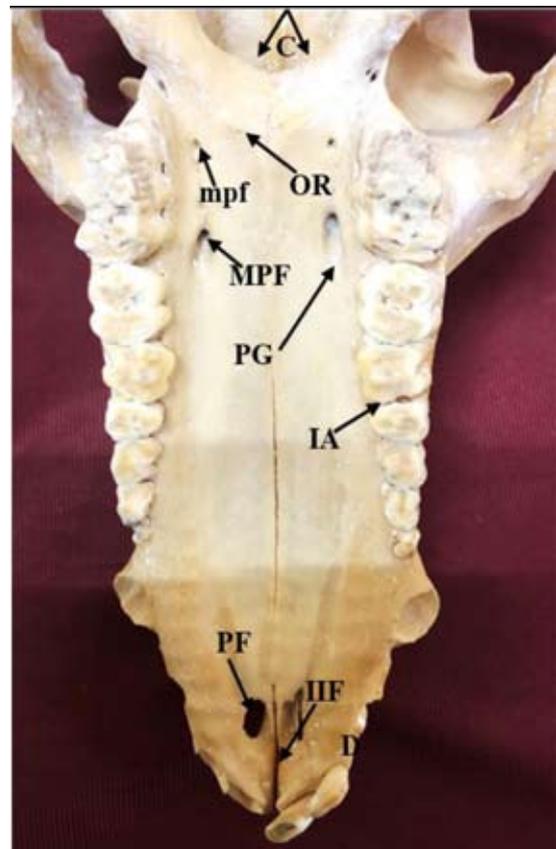
Sl. No.	Parameter- Width	Mean ± SE (cm)
1.	At 1 <sup>st</sup> incisor teeth level	$0.7 \pm 0.2$
2.	At 2 <sup>nd</sup> incisor teeth level	$2.7 \pm 0.3$
3.	At 3 <sup>rd</sup> incisor teeth level	$4.4 \pm 0.2$
4.	Just in front of canine tooth (At diastema)	$5.5 \pm 0.6$
5.	At canine teeth level	$5.3 \pm 0.7$
6.	Just behind canine tooth (At diastema)	$6.7 \pm 0.5$
7.	At 1 <sup>st</sup> premolar teeth level	$5.2 \pm 0.5$
8.	At 2 <sup>nd</sup> premolar teeth level	$4.7 \pm 0.4$
9.	At 3 <sup>rd</sup> premolar teeth level	$4.5 \pm 0.5$
10.	At 4 <sup>th</sup> premolar teeth level	$4.1 \pm 0.4$
11.	At 1 <sup>st</sup> molar teeth level	$4.0 \pm 0.5$
12.	At 2 <sup>nd</sup> molar teeth level	$3.8 \pm 0.3$
13.	At 3 <sup>rd</sup> molar teeth level	$3.3 \pm 0.4$
14.	Just behind the 3 <sup>rd</sup> molar tooth	$4.0 \pm 0.3$
15.	At posterior border of bony palate	$2.3 \pm 0.2$



**Fig. 1.** Photograph of bony palate of pig showing the palatine process of incisive bone (IB), maxilla (M) and horizontal part of palatine bone (HP). C- Canine teeth, CB- Caudal border of bony palate, D- Diastema, EC- Eminentia canina, I- Incisor teeth, IMS- Incisive maxillary suture, PMS- Palatomaxillary suture, PS- Mid-Palatine suture, VP- Vertical part of Palatine bone, PM1- 1<sup>st</sup> premolar tooth, PM2- 2<sup>nd</sup> premolar tooth, PM3- 3<sup>rd</sup> premolar tooth, PM4- 4<sup>th</sup> premolar tooth, M1- 1<sup>st</sup> molar tooth, M2- 2<sup>nd</sup> molar tooth, M3- 3<sup>rd</sup> molar tooth.

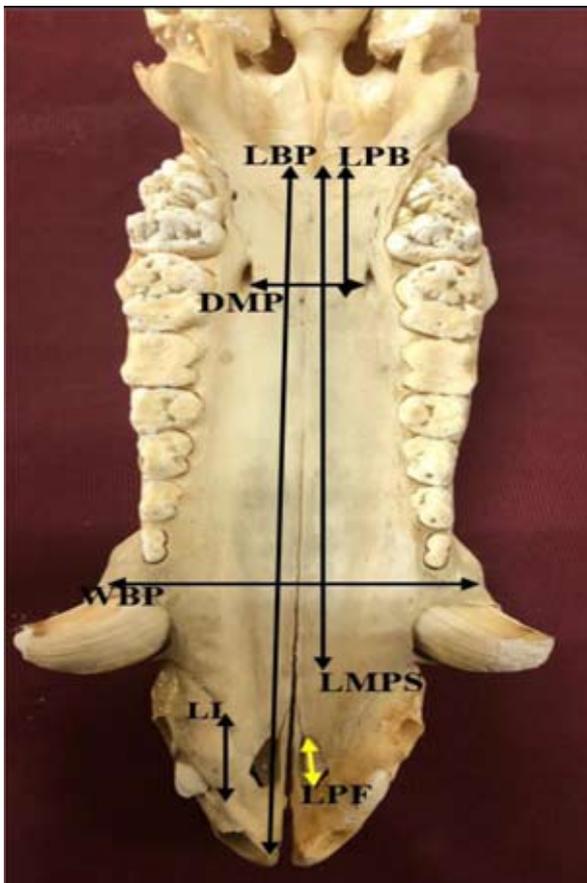
inter-incisive fissure to the posterior border of bony palate was  $15.6 \pm 1.5$  cm (Fig.3). The width of the bony palate gradually increased from the level of the first incisor teeth to just behind the canine teeth, measured  $0.7 \pm 0.2$  cm to  $6.7 \pm 0.5$  cm, respectively, while it gradually decreased from the level of the first premolar teeth to the level of the third molar teeth, measured  $5.2 \pm 0.5$  cm to  $3.3 \pm 0.4$  cm, respectively. The width of the bony palate slightly increased just behind the 3<sup>rd</sup> molar teeth ( $4.0 \pm 0.3$  cm), while in local Mizo pigs it was  $5.07 \pm 0.01$  cm (Choudhary et al., 2019) and in Mizoram goats it was  $4.73 \pm 0.03$  cm (Choudhary et al., 2020). The width of the bony palate decreased at the posterior border of the bony palate ( $2.3 \pm 0.2$  cm). The maximum width of the bony palate was  $6.7 \pm 0.5$  cm at canine tooth level (Table.1, Fig.3). In contrary to this finding, the maximum width of the bony palate was 3.3 cm between the fourth pair of cheek teeth in leopard cats (Sarma et al., 2001).

The present study reported that the fusion of the bodies and palatine processes of paired incisive bones at the midline was incomplete and leaving a narrow inter



**Fig.2.** Photograph of bony palate of pig showing the major palatine foramina (MPF), minor palatine foramina (mpf), palatine fissure (PF) and interincisive fissure (IIF). IA- Interalveolar space C- Choanae D- Diastema OR- Oblique ridges PG- Palatine groove.

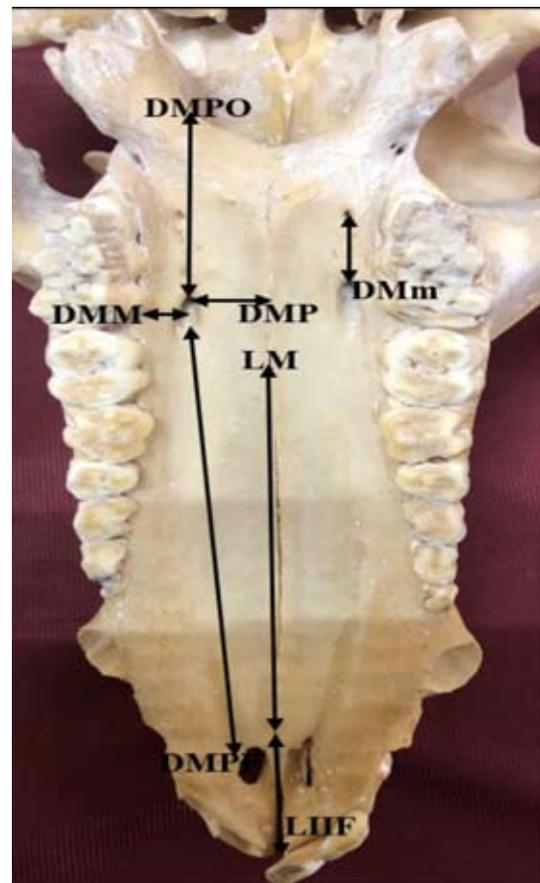
incisive fissure ( $4.7 \pm 0.5$ cm) along their length up to the interpalatine suture of maxillary bone, which was tapered caudally in the form of a long-drawn V (Figs.4,2), which was in accordance with the findings reported by Gupta *et al.* (1990) in buffaloes. In contrast to this finding, interincisive fissure was broad and notched rostrally with a tapering pointed end in ox and yak (Gupta et al., 1990). The alveolar processes of the bodies of incisive bones showed six alveolar sockets for the upper incisor teeth and formed the rostral alveolar arch of the bony palate (Fig.1) as reported in dogs by Evans and De Lahunta (2012). Short diastemas were found between the upper second and third incisors and also between the upper third incisor and upper canine teeth, and their lengths were recorded as  $0.7 \pm 0.4$  cm and  $1.1 \pm 0.5$  cm respectively (Figs.1,2). The incisive-maxillary suture in the bony palate was non-serrated and joined the palatine processes of the maxilla and the incisive bones (Fig.1). This suture opened into the palatine fissures in the cranio-medial aspects. The palatine fissures were elongated and oval, located rostrally. Similarly, Hillmann and Sisson (1975) also reported that the paired palatine fissures were located rostrally in pigs. The palatine fissures were bounded laterally by the palatine process of maxilla and the body of incisive bone, medially by the palatine process of the incisive bone, rostrally by the body of



**Fig. 3.** Photograph of bony palate of pig showing the length of bony palate (LBP), length of palatine fissure (LPF), length of palatine process of incisive bone (LI), length of horizontal part of palatine bone (LPB), length of mid-palatine suture (LMPS), distance between two major palatine foramina (DMP) and width of the bony palate just behind the canine teeth (WBP).

incisive bone and caudally by palatine process of maxilla. According to Mahdy and Mohammed (2021) in rabbits the palatine fissures were bounded medially by the palatine process of the incisive bone and vomer and laterally by the body of the incisive bone and the palatine process of the maxilla (Fig.2). The distance between two palatine fissures was  $0.5 \pm 0.2$  cm. The length and width of palatine fissure on right side were  $1.4 \pm 0.3$  cm and  $0.4 \pm 0.2$  cm respectively, while on the left side it was recorded as  $1.6 \pm 0.3$  cm and  $0.5 \pm 0.3$  cm respectively (Fig.3). The length of palatine process of incisive bone measured along the midline, from the rostral end of the palatine process of the incisive bone to its suture with the rostral edge of palatine process of the maxillary bone was  $3.5 \pm 0.3$  cm (Fig.3), while in Ghanaian local dogs it was  $2.075 \pm 0.649$  cm (Opoku-Agyemang et al., 2020).

In the present study, the mid palatine suture of maxilla was serrated or a plane type of suture, extending from inter incisive fissure rostrally to the serrated mid-palatomaxillary suture caudally (Fig.1). The palatine process of maxilla measured along the midline, from the rostral edge of the palatine process of the maxillary bone



**Fig. 4.** Photograph of bony palate of pig showing length of palatine process of maxilla (LM), length of inter-incisive fissure (LIIF), distance between major palatine foramen to palatine fissure (DMPF), distance between major palatine foramen to molar tooth socket (DMM), distance between major palatine foramina to mid-palatine suture (DMP), distance between major palatine foramina to posterior border of bony palate (DMPO), distance between major and minor palatine foramina (DMm).

to its suture with the palatine bone was recorded as  $12.3 \pm 0.8$  cm (Fig.4). The oral surface of palatine processes of maxilla was concave. Oval-shaped major palatine foramina were situated in the caudal part of palatine process of the maxilla, near its junction with the horizontal palatine bone towards the alveolar borders of maxilla and lateral to the palatomaxillary suture at the level of the junction between last two upper molar teeth on either side of mid-palatine suture (Fig. 2) which was in agreement with the findings of Doley et al. (2018) in wild boars. Similar to this in humans, the major palatine foramina were reported to be positioned close to the lateral palatal border of the palatomaxillary suture between or opposite the second and third molar teeth (Jotania et al., 2013). Contrary to the present finding, the greater palatine foramina were located medial or opposite to the 3rd maxillary molar tooth in humans (Ajmani, 1994). In the present study the major palatine foramina were situated entirely on the palatine process of the maxillary bone. Contrary to this finding, in leopard cats (Sarma et al., 2001) and in Indian black buck (Choudhary & Singh, 2016) the major palatine foramina

were reported to be located entirely in the palatine bone of the bony palate.

The palatine groves were elongated, shallow and slightly curved cranially towards the medial side and extended from the major palatine foramen caudally to the palatine fissure rostrally (Fig.2), which were similar to the observations of Doley et al. (2018) in wild boars. Contrary to the above finding, the palatine groves were reported as distinct only for a short distance in ruminants (Sisson, 1975), in ox, buffalo and yak (Gupta et al., 1990). The distance between two major palatine foramina was  $2.3 \pm 0.4$  cm (Fig.3) while in humans (Sarilita & Soames, 2015) it was  $2.76 \pm 0.277$  cm. In the present study the length and width of the right major palatine foramen was  $0.4 \pm 0.1$  cm and  $0.5 \pm 0.06$  cm respectively, while in the left side it was  $0.3 \pm 0.2$  cm and  $0.5 \pm 0.05$  cm respectively. Similarly, Sarilita & Soames (2015) reported that the maximum width of major palatine foramen was  $0.23 \pm 0.05$  cm in humans. In the present study the distance between the posterior border of bony palate to the major palatine foramina was  $3.7 \pm 0.5$  cm on right side and  $3.6 \pm 0.3$  cm on left side (Fig.4), while in humans (Badshah et al., 2018) it was  $0.405 \pm 0.126$  cm on right side and  $0.396 \pm 0.135$  cm on left side, whereas Gupta et al. (1990) reported that in buffalo it was 5.4 cm, in yak 3.5 cm and in ox it was 3 cm. The distance between the palatine fissure to major palatine foramina in the right side was  $12.5 \pm 0.3$  cm while in the left side it was  $12.3 \pm 0.3$  cm. The distance between major palatine foramina to the molar tooth socket was recorded as  $0.6 \pm 0.1$  cm on the right side and  $0.5 \pm 0.1$  cm on the left side (Fig.4). The distance between the mid palatine suture to major palatine foramina was recorded as  $1.2 \pm 0.2$  cm on right side and  $1.1 \pm 0.2$  cm on left side (Fig.4), while in buffalo it was 1.6 cm, in ox 1.4 cm and in yak 1.5 cm, which was reported by Gupta et al. (1990), in humans it was  $1.38 \pm 0.15$  cm (Sarilita & Soames, 2015). In this study, the distance between major and minor palatine foramina was recorded as  $1.5 \pm 0.6$  cm. The alveolar processes of the maxillae bone showed fourteen alveolar sockets for upper cheek teeth and two large alveoli for the upper canine teeth, which forms the lateral borders of the bony palate (Fig.1). Eminentia canina was a projection observed at the cranial extent of the alveolar processes of the maxilla bone (Fig.1). A short diastema was found between the upper canine tooth and the upper first premolar tooth and it was measured as  $1.2 \pm 0.4$  cm (Fig.1). The above observations were in acceptance with the reports of Mohamed (2019) in wild boars.

In the present study the palatine surface of the horizontal part of the palatine bones formed caudal one-fourth of the bony palate and appeared triangular, with the base caudally and apex rostrally. The apex was pointed and interposed in the caudal edges of palatine process of maxilla (Fig. 1). Two plates of horizontal parts of palatine bone were fused at the midline. These findings were in agreement with the Hillmann and Sisson (1975) in pigs.

Caudally, the bony palate showed a centrally projecting spine with a shallow notch (Fig.1). Contrary to this, the caudal border of the bony palate exhibited a median eminence, the caudal nasal spine without any notch as reported by Evans and De Lahunta (2012) in dogs. In the present study on either side of the mid-palatine suture oblique ridges extending from caudal part of mid-palatine suture to vertical part of palatine bone were observed (Fig.2). Similar to the above finding, the horizontal part of the palatine bone presented two elongated elevations on either side of the median plane as reported by Sarma et al. (2001) in leopard cats. The length of horizontal part of palatine bone measured along the midline, from the posterior border of bony palate to its suture with the palatine process of the maxillary bone was  $4.6 \pm 0.5$  cm (Fig.3), while in Ghanaian local dogs it was  $5.251 \pm 0.954$  cm (Opoku-Agyemang et al., 2020). Two to three oval-shaped minor palatine foramina were present on either side of the mid palatine suture, close to the lateral palatomaxillary suture and at the level of 3<sup>rd</sup> molar tooth (Fig.2), which concurs with the findings of Hillmann and Sisson (1975) in pigs. Contrary to this finding, Hillmann (1975) reported that several minor palatine foramina scattered along each side of the palate in equines, while in humans one to six minor palatine foramina were located on either side of the bony palate (Sarilita & Soames, 2015), a few accessory minor palatine foramina were present in the bony palate of ox, buffalo and yak as reported by Gupta et al. (1990) and minor palatine foramina were absent in leopard cats (Sarma et al.,2001).

In the present study the average palatine index was recorded as  $32.3 \pm 1.2$  % in pig, while it was reported as 26% in buffalo, 30% in yak and 31% in ox by Gupta et al. (1990).

## Conclusion

The gross anatomical organization of the bony palate in the domestic pig reflects its role in providing structural support for mastication and effective separation of the oral and nasal cavities. Its composite formation by the incisive, maxillary and palatine bones ensures rigidity and functional stability, while regional variations in palatal width and length accommodate the dental arches and masticatory forces. The arrangement of palatine fissures, major and minor palatine foramina and palatine grooves facilitates the passage of neurovascular structures, and the well-defined mid-palatine suture with oblique ridges strengthens the palatal framework, indicating clear species-specific adaptations. Overall, the present study provides detailed morphological and morphometrical baseline data on the hard palate of the domestic pig, which are valuable for comparative and functional anatomical studies and have direct clinical relevance in veterinary dentistry, regional anaesthesia and oral surgical procedures. Furthermore, as pigs serve as important experimental and translational models, the generated data can be effectively applied in

biomedical, dental and craniofacial research, as well as in veterinary education and reference standards.

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