# Morphology and Pattern Study of Cranial Suture Joints in Adult Stray Dogs (*Canis familiaris*) from Saudi Arabia

Estudio de la Morfología y los Patrones de las Suturas Craneales en Perros Callejeros Adultos (*Canis familiaris*) de Arabia Saudita

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**SUMMARY:** A suture joint is a fibrous joint that does not move and are called fixed joints. The cranial joints of the skull are suture joints. The sutures of dog skull were viewed in dorsal, ventral, lateral-vertical and internal directions. The sutures of the dog skull are categorized into four groups: coronal, serrated, plane and squamosal sutures in different cranial positions. The current study aims to show the fibrous connections of the suture type in the stray dog and compare them with what is known about other domesticated dogs. We used 6 skulls of adult stray dog. The study found that the skull consists of nineteen bones — six single and 13 paired - most of which are connected by suture joints which is in agreement with previously reported studies of dog skull anatomy. However, the incisors and nasal bones are not connected in the stray dogs leading to the absence of a naos-maxillary-incisive notch. Other reports identified the maxilla articulates dorsally with the nasal bone and rostro-ventrally with the incisal bone to form a naos-maxillary-incisive notch, which has not been reported in other dog skull studies. Suture closure shows less closing in stray dogs in comparison to domestic dogs, but more closing than in wolves. This information is important to help veterinarians to distinguish sutures from fractures that may have occurred in the skull of dogs based on radiographs. The results of this study are also important for enriching comparative anatomy in different animal species.

KEY WORDS: Morphology; Skull; Sutures; Stray Dog; Pet Animal.

## INTRODUCTION

The skull is the most complex bony shape. It consists of 36 different bones, many of which are arranged in pairs and some individually; most of these bones are joined together by sutures. The cranial suture consists of contiguous margins of the cranial bones. Some sutures extend from the sides and front of the skull to the back. The suture connections show morphological differences between the bones. Sutures help to shape the face by firmly connecting the surrounding skull bones. Sutures form a firm connection and prevent most movement between the bones. Most sutures are named after the bones to which they articulate, but others have unique names (White *et al.*, 2021).

Little is known about the relationship between cranial conformation and the particular patterns of suture in stray dogs. Fibrous joints are found between flat bones in the craniofacial skull in horses, which allow for restricted movement (Rice, 2008). Sutures are fibrous joints which occur between flat bones or between flat bones and endochondral bones in the vertebrate skull (Rice, 2008). The sutures are not only the primary sites of osteogenesis in the skull, but also serve to connect neighboring bones (White *et al.*, 2021). The sutures allow the neighboring bones to develop at their edges through intramembranous osteogenesis (White *et al.*, 2021). The shape of the skull refers to the configuration of the joints between the cranial bones, which have been shown to form a complete suture or a cleft-like structure in the zygomatic and parietal bones in various domestic animals (Miroshnikova *et al.*, 2022). It has been found that cranial suture closures significantly differ between domesticated dog species (Geiger & Haussman, 2016).

Stray dogs are distributed all over Saudi Arabia and causing several problems where they live around cities and towns. First, they can transmit zoonotic diseases such as rabies and Echinococcus granulosus. Second, they attack people and livestock animals. Finally, they can interbreed with wild wolves which might lead to the reduction of wild species.

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We hypothesis that stray dog skull cranial sutures differ from domesticated dogs due to the nature of their environment. To test our hypothesis, we used 6 adult stray dog skulls to observe the most anatomical characteristics of suture joints.

## MATERIAL AND METHOD

In this study, we used 6 adult stray dog skulls mean age 4.5 years that were boiled in water with 30 % sodium hydroxide (NaOH) for 6 h. The skulls were dried at room temperature for 48 h. They were then preserved in 99 % hydrogen peroxide solution for 48 h and then dried for three days (Allouch, 2014). The shape and morphology of the sutures were examined in this work. The anatomical descriptions included a detailed examination of the cranial sutures in their entirety. Numerous cranial sutures were examined with the observing eye, and photographs of the cranial sutures were taken in the mediolateral, anteromedial, ventro-dorsal and dorsoventral directions.

#### RESULTS

Based on the surface of observation:

**The dorsal group:** This collection of sutures is visible from the dorsal and dorsolateral surface. It contains the articular points for the nasal, frontal, parietal, parietal and lacrimal bones.

- 1. Internasal surface suture: This is a single, straight suture that begins at the tip of the nasal bone and runs caudally to the frontal suture. It is located halfway rostral to the facial skull between two nasal bones (Fig. 1, A and B; 1).
- 2. Nasomaxillary surface suture: It is paired and has flat margins and extends over most of the nasal and maxillary bones. The maxillary bone articulates dorsally and horizontally with the nasal bone and forms the nasomaxillary suture (Fig. 1, A and B; 2; Fig. 2, C and D; 2).
- 3.Nasofrontal suture: It is paired and short and is located between the caudal portions of the nasal bones and the cranial margins of the frontal bones. It is located more caudally than the frontal suture of the maxilla. The frontonasal suture has more serrations than the frontal and internal sutures (Fig. 1, A and B; 3).
- 4. The frontal plane suture: The frontal suture is straight and shorter than the internasal suture. It is a vertical suture that connects the right and left frontal halves. Due to the stronger ossification in the frontal region, the suture is less pronounced than the nasal suture (Fig. 1 A and B; 4).
- 5. Coronal suture: It is also known as the frontoparietal suture. It runs between the caudal edges of the frontal bone and

the cranioventral edges of the parietal bones. It is jagged, smooth and barely noticeable. The coronal suture between the frontal and parietal bones is displaced to the synostosis, where the parietal and frontal bones are fused together. The edges of the two bones are indistinguishable without closer inspection (Fig. 1, A and B; 5, Fig. 2, C; 8).

- 6. Sagittal plane suture: or parietal plane suture This is a single suture that runs from the coronal suture rostrally to the nuchal crest caudally, where the two parietal bones meet in the midline and form a synostosis (Fig. 1, A and B; 6).
- 7. Parieto-occipital serrate suture: It is called the lambdoid suture: the suture between the two parietal bones and the occipital bone. It runs transversely from the back of the skull (Fig. 1, A and B; 7).
- 8. Front maxillary serrate suture: Bilateral, curved, thin and serrated, they connect the cranial margins of the frontal bones to the caudal margins of the maxillary bones and extend the maxillo-lacrimal suture (Fig. 1, A and B; 8).



Fig. 1. Dorsal view of the skull showing the position of the cranial sutures. (A,B): (1) Internasal suture, (2) Nasomaxillary suture, (3) Nasofrontal suture, (4) Frontal suture, (5) Coronal suture, (6) Sagittal suture, (7) Parito-occipital suture. (B): (8) Fronto-maxillary suture.

**The lateral group:** The sutures in this group are paired and may be visible from the side. These include the incisive, maxillary, lacrimal, zygomatic and temporal sutures.

- 1. Incisivomaxillary serrate: It has a curved shape and is formed between the palatal process of the premaxilla and the palatal process of the maxilla and meets the nasomaxillary suture dorsolaterally (Fig. 2, C and D; 1).
- 2. Maxillo-lacrimal serratus suture: Located rostral to the orbit of the skull, it has unequal margins along the suture on the lacrimal bone and articulates horizontally with the zygomatic bone (Fig. 2, C; 3).
- 3. Zygomaticomaxillary serrate suture (Fig. C,4; D,3):This is a cranial suture between the maxilla and the zygomatic bone, at the floor of the orbit. The maxillary bone meets the zygomatic bone vertically. This suture has an irregular and short margin between the two bones (Fig. 2, C; 4 and D; 3).
- 4. Zygomaticotemporal suture: The zygomatotemporal suture is the connection between the zygomatic bone and the temporal bone. It is part of the zygomatic arch. Attachment of the zygomatic process of the temporal bone and the temporal process of the zygomatic bone by the flat edges (Fig. 2, C; 5 and D; 4)



Fig. 2. Lateral view of the skull showing the location of the cranial sutures. (C): (1) incisor-maxillary suture, (2) nasomaxillary suture, (3) maxillro-lacrimal suture, (4) zygo-maxillary suture, (5) zygo-temporal suture, (6) squamous-temporal suture, (7) occipito-temporal suture, (8) lamboid suture. (D): (1) incisor-maxillary suture (2) nasomaxillary suture, (3) zygo-maxillary suture (4) zygo-temporal suture, (5) coronal suture (6) squamous-temporal suture, (7) occipito-temporal suture, (8) lamboid suture.

- 5. Squamosal-temporal suture: The squamosal suture runs horizontally caudally from the middle part of the parietal bone and connects the temporal bone to the lower edge of the parietal bone: this suture continues behind the short, almost horizontal parietomastoid suture that connects the mastoid process of the temporal bone (Fig. 2, C and D; 6).
- 6. Occipital-temporal squamosal suture: the occipitomastoid suture or occipitotemporalis suture is a cranial suture that connects the cranial margin of the occipital squamosal to the mastoid portion of the temporal bone (Fig. 2, C and D; 7).
- 7. Lambdan suture (Fig. C,8; D,8): It is called the parieto-occipital serrate suture (sutura serrata parieto-occipitalis), is located at the end of the skull between the two parietal and occipital bones and forms a dens -shape. It is continuous with the occipital-mastoid suture, which connects the occipital bone with the mastoid part of the temporal bones (Fig. 2, C and D; 8).

**The ventral group:** includes the cranial sutures that are visible from the ventral view. This also includes the sutures that are connected to the palatine bone, the pterygoid, the sphenoid bone, the temporal bone and the occipital bone.

- 1. The sutura plana premaxillaris:, also called the incisor suture, is the anterior palatal suture that appears as a linear suture outlining the palatine process of the premaxilla and the palatine process of the maxilla (Fig. 3, E; 1).
- 2. The median palatal suture: The median palatal suture is located at the midline of the hard palate. It originates at the fusion line of the horizontal plates of the palatal processes of the maxillary bone in the median plane. It runs rostrally through the inter-incisive suture and continues the transverse palatal suture causally. It runs rostrally through the inter-incisive suture and continues the transverse palatal suture causally. It runs rostrally through the inter-incisive suture and continues the transverse palatal suture causally (Fig. 3, E; 2 and F; 1).
- 3. The transverse palatal suture: It is a cranial suture that connects the maxillary palatal process with the palatal bone. It occurs when the two palatal bones meet the maxillary bone (Fig. 3, E; 3).
- 4. Spheno-vomeric foliate suture: It is a cranial suture that connects the rostral part of the pre-sphenoidal part of the sphenoid bone and the caudal end of the vomer bone ventrally to the nasal septum (it has very small articular margins (Fig. 3, E; 4 and F; 2).
- 5. Spheno-maxillary serrate suture: The first part is leafshaped and connects the presphenoidal part of the sphenoid bone to the ventral aspect of the rostral part of the roof of the maxillary bone, while the second part is flat and connects the maxillary bone to the basisphenoidal part of the sphenoid bone and the maxillary bone (Fig. 3, E; 5 and F; 3).

- 6. Spheno-pterygoid planar suture: It is the connection between the wings of the sphenoid bone and the pterygoid bone. In some specimens, there was a junction between the pterygoid, sphenoid and maxillary bones called the pterygoid-sphenoid-maxillary suture. It has a curved shape that follows the vertical course of the palatine-maxillary-sphenoid bones (Fig. 3, E; 6 and F; 4).
- 7. Spheno-petrosal plane suture: The sphenoid-petrosal temporal suture or spheno-squamosal suture connects the caudal margin of the greater wing of the sphenoid bone with the cranial margin of the squamous epithelium of the temporal bone. It lies directly lateral to the foramen oval and forms part of the caudal wall of the foramen lacerum (Fig. 3, E; 7 and F; 5).
- 8. Tympanopetrousal plane suture: It lies between the cranial edge of the tympanopetrousal and petrous parts of the temporal bone (Fig. 3, E; 8 and F; 6).
- 9. Squamosopetrous suture: This is a small arch that connects the squamous parts and the petrous part of the temporal bone (Fig. 3, E; 9 and F; 7).





## DISCUSSION

Sutures fulfill a variety of functions by enabling growth and compensating for stresses during development. This makes them an interesting topic for studying the function and development on anatomy. Sutures connect all bones of the skull except the mandible. Sutures in the skull vary according to bone shape and size, especially in dogs. Knowledge of the normal architecture and development of sutures is critical to understanding faulty suture development and the ability to differentiate sutures radiographically from normal anatomical structures and potential skull fractures found that most of the bones.

Our results are consistent with previously reported studies in domestic animals, where differences between animals were found to be influenced by the joint configuration of the skull bones and adjacent bones, including the maxilla, lacrimal and incisor bones (Miroshnikova et al., 2022). Thus, the internasal and nasal sutures are remarkably straight in the stray dogs. Thus, most of the bones are connected by sutures and are isolated sutural bones of different shapes and sizes. These results are consistent with Cohen Jr. (1993) and Persson (1995), who found that sutures play an important role in appositional bone formation throughout cranial development. Klein et al. (2019), discovered that the sutures are not always placed in the same anatomical region. Our study found that although the location remains constant, it becomes less conspicuous over time due to ossification.

Our results show that bone development around suture joints are well developed and suture closure shows lower closing edges comparing to domesticated dog breeds but greater than wolves (Geiger & Haussman, 2016). This was expected due to lifestyle of stray dogs that are not domesticated animals, but still live around cities and towns, nor are wild animals, such as wolves. The connection between the facial and cranial bones and surrounding bones, such as the maxilla and others, has been shown to be a continuous suture or fissure-like structure in various domestic animals (Hermanson & De Lahunta, 2018).

Fig. 3. Ventral view of the skull, showing the location of the cranial sutures. (E): (1) premaxillary (incisive) suture, (2) palatine-median suture, (3) palatine-transverse suture, (4) spheno-vomeric suture, (5) spheno-maxillary suture, (6) spheno-pterygoid suture, (7) spheno-pertrosal suture, (8) tympanic-petrous suture, (9) squamous-petrous suture. (F): (1) median palatine suture, (2) spheno-vomeric suture, (3) spheno-maxillary suture, (4) spheno-pterygoid suture, (5) spheno-pertrosal suture, (6) tympanic-petrous suture, (7) squamous-petrous suture.

The coronal suture of the stray dog was smooth and inconspicuous. These results contradict with Capitan *et al.* (2011), who reported that synostosis of the cranial coronal suture in cattle. However, the frontonasal suture was found to have a higher degree of interdigitation than the other sutures (Rafferty & Herring, 1999).

The incisor bones are exclusively in contact with the maxillary bones. This result is in agreement with what has been found in dogs, sheep, cattle and camels. On the other hand, the corresponding results contradict with Yahaya *et al.* (2012) who claimed that the incisor bone in camels is connected cauda-dorsally to the maxillary and nasal bones.

In this study, the median palatal suture was formed at the fusion line of the horizontal plates of the maxillary palatal processes, while the transverse palatal suture was formed by the unit two of the palatine bones and the maxillary palatal process. These results are in agreement with those of Allouch & Alshambari (2022), in camels (Allouch & Alshanbari 2022). On the other hand, Goswami *et al.* (2013), reported that carnivores differ from other mammalian groups by a great diversity of palatal suture closure, with no correlation between size and degree of suture closure. However, the palate was U-shaped, with a straight and smooth median palatal suture. The transverse palatal suture was V-shaped and jagged, overlying the larger palatal foramina of the goat (Sarma, 2006).

Our results show that the maxilla articulates dorsally with the nasal bone and rostro-ventrally with the incisal bone. However, the incisors and nasal bones are not connected in the stray dogs leading to the absence of a naos-maxillaryincisive notch. In other domesticated dog breeds, the maxilla articulates dorsally with the nasal bone and rostro-ventrally with the incisal bone to form a naos-maxillary-incisive notch (Buzek *et al.*, 2022).

Many sutures in stray dogs do not close completely with the dental, facial and craniofacial sutures. In fact, the craniofacial sutures are the least closed. These results are consistent with Carnivora and camels (Goswami *et al.*, 2013; Choudhary *et al.*, 2021).

The caudal projection of the naos frontal suture is narrower than that of the maxillary frontal suture in stray dogs in this study. This result is in agreement with what has been found in horses (Dyce *et al.*, 2017). However, Raghavan (1964) and Reda (2019) found that the naos frontal suture is wider than that of the maxillary frontal suture in oxen and lions respectively (Mohamed, 2019). On the other hand, the frontomaxillary suture does not meet continuously and may be absent in certain camels (Yahaya *et al.*, 2012). Because dogs lack a zygomatic process at the junction of the frontal and zygomatic bones, the nasofrontomaxillary suture detected in this study cannot be classified as a nasolacrimal fissure. This is similar to what was reported in dogs, horses, cattle, and goats (Evans & De Lahunta, 2012; Dyce *et al.*, 2017). In addition, the small size of the canine lacrimal bone prevents it from contacting the nasal and maxillary bones, as has been observed in dogs, cattle, goats and horses (Evans & De Lahunta, 2012; Dyce *et al.*, 2017). The parietal and interparietal suture rested on the nuchal transverse crest as shown in the bovine skull (Raghavan, 1964). On the other hand, anatomical analysis of canine skulls shows considerable differences in the shape of the occipitoparietal suture in dogs (Bradley, 1908).

The current study shows that the naos-frontal suture is irregularly margined and has greater interdigitation than the other sutures. The inner surfaces of the interparietal sutures in dogs are flat or uneven. Similar findings were also noted in dogs (Herring, 1972), and goats (Sarma, 2006). We also show that the occipital bone connects the parietal bone via the transverse suture. This result is consistent with what was discovered in dogs and camels (Allouch & Alshanbari, 2022; Ahani *et al.*, 2024). In contrast to our findings, Choudhary *et al.* (2021), reported that the occipitaltemporal suture in camels is located between the occipital and the parietal bone in the caudal region.

The results show that the lambdoid suture is located at the end of the skull between the two parietal and occipital bones and forms a dens (?)-shape. Similar findings have been reported in previous studies in goats (Sarma, 2006). Balolia (2015) reported that in dogs, the degree of spheno-occipital fusion is a potential predictor of relative maturity, particularly in great apes.

Goswami *et al.* (2013) in carnivores confirms the consistent finding that the skull becomes more fused with increasing size. In addition, the author has examined the relationship between skull length and suture closure in Carnivora to determine if it is similar in other mammalian groups. Sutures are essential points of flexibility that transmit loads during muscular work or traumatic impacts. Different feeding techniques and lifestyles can influence the degree of suture closure in domestic dogs and wolves (Geiger & Haussman, 2016).

### CONCLUSION

This work has provided a solid foundation for the description of stray dogs' cranial suture types, including coronal, serrate, plane, squamosal and foliate, which differ from those of other mammals. The suture has been extensively studied as a model system. Sutures in various forms connect the bones of the skull. Sutures serve as anatomical landmarks for surgical procedures on the neurocranium, where the brain, arteries and veins are located. These sutures serve as important anatomical landmarks for surgical procedures in the closed box of the neurocranium, where the brain, arteries and venous sinuses are located. In this study, we show the stray dog sutures which can be used to compare them with domestic dog and wolf sutures.

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**ALLOUCH, G. M. & ALSHANBARI, F. A.** Estudio de la morfología y los patrones de las suturas craneales en perros callejeros adultos (*Canis familiaris*) de Arabia Saudita. *Int. J. Morphol.*, 43(3):962-967, 2025.

**RESUMEN**: Una sutura es una articulación fibrosa inmóvil, denominada articulación fija. Las suturas craneales del cráneo se observaron en dirección dorsal, ventral, latero-vertical e interna. Las suturas del cráneo canino se clasifican en cuatro grupos: coronal, serrada, plana y escamosa en diferentes posiciones craneales. El presente estudio pretende mostrar las conexiones fibrosas del tipo de sutura en perros callejeros y compararlas con el conocimiento sobre otros perros domésticos. Se utilizaron seis cráneos de perros callejeros adultos. El estudio reveló que el cráneo consta de diecinueve huesos (seis impares y trece pares), la mayoría de los cuales están conectados mediante suturas, lo cual concuerda con estudios previos sobre la anatomía del cráneo canino. Sin embargo, los incisivos y los huesos nasales no están conectados en los perros callejeros, lo que provoca la ausencia de una incisura naso-maxilar-incisiva. Otros estudios identificaron que el maxilar se articula dorsalmente con el hueso nasal y rostro-ventralmente con el hueso incisal para formar una incisura naso-maxilar-incisiva, algo que no se ha reportado en otros estudios sobre cráneos caninos. El cierre de las suturas muestra un menor cierre en los perros callejeros en comparación con los perros domésticos, pero un mayor cierre que en los lobos. Esta información es importante para ayudar a los veterinarios a distinguir las suturas de las fracturas que puedan haberse producido en el cráneo de los perros basándose en radiografías. Los resultados de este estudio también son importantes para enriquecer la anatomía comparada en diferentes especies animales.

PALABRAS CLAVE: Morfología; Cráneo; Suturas; Perro callejero; Mascotas.

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