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ARTICLE

Anatomical Classifications of Accessory Symphyseal Foramina in Infants, Juveniles and Adults Raccoon (*Procyonoides nyctereutes*) Mandibles

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ABSTRACT

The aim of this investigation was to assess the pattern of occurrence of accessory foramina in infants, juveniles and adult raccoons (*Procyonoides nyctereutes)*. The study utilized a total of forty (40) mandibles including thirteen (13) infantile (pups), twelve (12) juveniles and fifteen (15) adult mandibles, studied grossly for frequency, position and diameter of the foramina. In 80% of the evaluated adult mandibles, at least one accessory foramen was found and supero-laterally located. In all juveniles (100%) at least one accessory foramen was present, and located mostly near the midline about half-way of the symphyseal length while in pups (94%) at least a foramen was present, and in all cases located at or near the sympyseal line (rostral third or caudal third) to the dorsal ridge but never central. Five distinct co-existence types were used in their classification into foramina as categories I a-d, II a-c, III, IV and V. The frequency, size and location varied between the age groups; category 1 types occurred in 33%, 33% and 30% of adults, juveniles and pups respectively, category II in 33%, 42% and 54%; category III, 3.8%, 2.2% and 5.8%; category IV,1.9%, 4.4% and 11.7%; category V, 3.8%, 2.2% and 0%; respectively. Accessory symphyseal foramina are structural occurrences in raccoon mandible with size, frequency and position variations depending on classification type. There were no significant variations in the accessory symphyseal foramina assessed within pups. This work gives baseline information on the phenotypes of accessory mental foramen in post natal development in the raccoons.

Keywords- Raccoons, Mandibles, Accessory foramina, Symphyseal ridge

INTRODUCTION

Ontogenic and structural mandibular variations occur among animal species (Przystanska and Bruska, 2012**)** including man, one such is the occurrence of accessory mandible foramen. Hidaka *et al.* (1998); Kauhala *et al.,* (1998) compared mandible architecture in terms of relative and absolute robustness among both Finnish and Japanese raccoons with no reference to non-metric traits. Jurgelenas *et al.* (2007) investigated raccoon skulls from Lithuania while Okano (1974) studied craniometric interdependences in Polish species. Accessory foramen appears more in the anterior parts than posterior (McDonnell *et al.,*

1994; Onar *et al*. 2001) and has been described as lingual when found on the internal surface of the mandible (McDonnell et al., 1994; Chapnick, 1980) and this type occurs more frequently than the labial (when on the external surface) as seen in *Homo sapiens* and *canis familiaris* (Onar *et al.,* (2001); Smith (1999). Despite numerous positional nomenclatures given to these foramina; foramen below the genial tubercle in man; named inferior lingual foramen (Shiller and Wiswell, 1954), whereas those in the lateral regions are termed lateral retro-mental (Madeira *et al.,* 1978), however, co-existence ambiguities still exists in the descriptive morphology of these structures in raccoons; where such occurrences prevail more on the external or labial surface of the mandible compared to the *Canis familiaris* (Smith, 1999).

There is paucity of literature on accessory foramina in raccoon's mandibles of different age groups. This is to the best of our awareness the first attempt at such categorical approach and perspective in this species. The necessity to establish epigenetic nature of this feature, constancy of its presence in early life, as well to observe location and topographic differences when compared to adults justifies this study. This is relevant in population studies, surveillance and in solving taxonomic ambiguities in different geographic locations at particular times.

MATERIALS and METHODS

Animals

The present evaluation was done on a total of forty mandibles obtained from forty *Procyonoides nyctereutes* species taken in the wild from the south-western region of Nigeria. Animals were grouped to age categories using on standard body length and dental eruptions into adults, juveniles and pups based on the works of Androukaki *et al*. (2002), Koepfli *et al,* (1994) and Olopade and Okandeji (2010). Skull maceration process after cervical decapitation was according to Onar (2001). Experiments were done in accordance with the guidelines of ethical committee of Faculty of Veterinary Medicine University of Ibadan, Nigeria:

Locational topography

For precise locations, foramen dimensions were taken using calibrated optical lenses; also relative distances from tip of the alveolar sockets, the symphyseal ridge and line were recorded. The vertical and horizontal location of each foramen in relation to mandible symphyseal height was expressed in percentage (%). For lateral foramina; both co-ordinates were taken for left and right hemi mandibles from the midline. Similar method of deductive evaluations was carried out on all age groups of classified mandibles. Picture images were taken with CANON EOI 1200D digital cameras equipped with EFS 18-55mm telephoto kit and pictures taken using 5.6 focal, 200 speed, DIN-25cm, and sensitivity of 1/500 with image stabilizer and HAMA® tripod for linear assessment of landmarks

Morphology

We identified five different category types of accessory symphyseal foramina observed on the labial surface of mandibles studied.

Position for Figure 1

Landmark dimensions

A total of five (5) linear measurements were obtained from the mandibles, some as shown in figure 1a-h above

1. ***(S-F-d)-***Symphyseal ridge to foramen distance- measured in a horizontal plane (Fig.1a)
2. **(*Mh*)-** Mandibular height measured from the base of mandible to the coronoid process (Fig. 1c)
3. ***(A-F-d)***-Alveolar socket distance from the most dorsal foramina (Fig. 1d)
4. ***(S-L)***- Symphyseal lengths- measured from the direct ventral and midline limit of the mandibular symphysis to the tip of the midline alveolar socket dorsally (Fig. 1b).
5. ***(F%-Mh)-*** Foramen location ratio of mandibular height expressed in percentages (L/***Mh*** x 100) where L= distance from base of mandible.to foramen location

Statistical assessments were achieved with the use of STATISTICA 10 software (statSoft Inc. Tulsa (OK) using basic statistic methods of

multiple regressions and histogram distributions.

TABLE I: PERCENTAGE OCCURRENCE OF ACCESSORY FORAMINA IN THE MANDIBLES OF ADULTS, JUVENILES AND PUPS OF P. NYCTEREUTES

	Adults	Juveniles	Pups
Total number evaluated	15	12	13
Total number of foramina observed	52	36	17
Accessory foramina supero-lateral to the symphyseal ridge	24 (46%)	20(55%)	10 (59%)
Accessory foramina lateral to the symphyseal ridge (right)	10 (19%)	11(31%)	5 (12%)
Accessory foramina lateral to the symphyseal ridge (left)	3(6%)	8(22%)	2 (6%)
Accessory foramina midline of symphyseal line	4(8%)	3 (8%)	0 (%)
Category 1 including cat.	(9%)	(11%)	(11%)
1a-	2	1	2
1b-	2	1	0
1c-	1	2	0
1d	0	0	2
Category II	(7%)	(14%)	(21%)
Including cat. 2a-	2	1	3
2b-	2	2	4
2c	1	2	0
Category III	2 (3.2%)	1(2.2%)	1(4.6%)
Category IV	1(1.3%)	2(3.1%)	2(7.1%)
Category V	2(3.3%)	1(2.2%)	0(0%)

RESULTS

Accessory foramina occurred both unilaterally and bilaterally but never more than four in any one mandible. In eight mandibles, the foramen occurred on the right side, in ten; on the left. Bilaterally, it was observed to occur on both sides in eight mandibles. Observations revealed more frequency of accessory foramina in the upper one-third of symphyseal length (73%) than a significantly reduced (50%) occurrence in the lower third (see table). Mean position of the foramina was observed as 30% of symphyseal length, while the diameter ranged from 0.1-0.2mm.

Five distinct types of accessory foramina based on their location and co-existence were documented. This has been classified into five different categories: Category representative group types of accessory symphyseal foramina.

Cat. I Accessory foramina occurring both unilaterally and bilaterally in

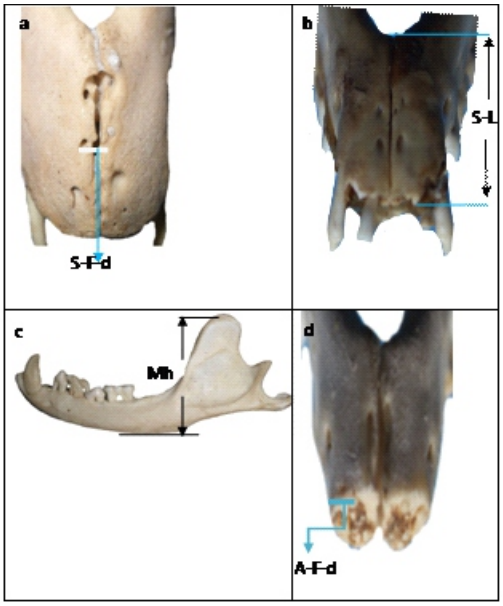


Fig. 1a, b, c and d showing some landmarks assessed in *P nyctereutes* mandible

dorso-lateral or midline unaccompanied by a lateral foramen was present in 13 mandibles (31%) and subdivided into 4 types:

Cat.I. type (a) Both foramina at the level of alveolar surface were found in 12% of mandibles or 4.4% of foramina investigated (Fig. 1a and 4a).

Type (b) both midline foramina dorsal and almost on the symphyseal line was observed in 7.5% of mandibles or 2.6% of foramina assessed (Fig. 1d and 4b).

Type (c) Single foramen located in the midline superior or within the symphyseal ridge occurred in 2 cases (7%) of mandibles or 1.75% of foramina (Fig. 4b).

Type (d) single foramen located midline but inferior to the symphyseal ridge observed in 5% of mandibles (Fig. 2b).

Category II was characterized by midline foramina superior or inferior to the symphyseal ridge accompanied by lateral foramina, observed in 42% of evaluated mandibles and subdivided into 3 types

Cat. II type (a) two midline foramina present superior to the smphyseal ridge and accompanied by a lateral foramen dorsal or ventral third of the symphyseal line occurred in 6 cases (15%) (Fig. 2a)

Cat. II type (b) two midline foramina superior to this ridge and found accompanied by two lateral foramina dorsal or ventral third of symphyseal line occurred in 8 cases (20%) (Fig. 1d)

Cat. II type (c) midline foramen located inferiorly to the ridge and accompanied by one or two lateral foramina was found in 3 cases (7.5%) or (6 foramina) (Fig. 3a).

Cat. III. In this group only foramina lateral to the symphyseal ridge was considered occurring in (10%) of mandibles evaluated. Unilateral foramina occurred on the left side (45%) of affected mandibles in this group, but in 10% bilaterally of the studied mandibles (Fig. 1a).

Cat. IV. Infero-lateral foramina to the ridge only occurred in 11.5% of mandibles assessed (Fig. 1a and 2b).

Cat. V. midline accessory foramina in the inferior third of symphyseal length was found in 3 mandibles (5.5%) (Fig. 3b).

Pups mandibles

The mean mandible height was 0.96±0.03cm. While the symphyseal length average was 1.3±0.02cm, a total of 17 accessory symphyseal foramina varied from 0 (1 specimen) to 4 (12 specimens). In 16 of the 17 accessory foramina (94%), at least a foramen was present, and in all these cases it was located midline dorsal, midline symphyseal and midline inferior (lower) to the dorsal ridge but never central (Fig. 2a).

Accessory foramina lying supero-lateral (dorsal and lateral) to the symphyseal (Fig. 1b) ridge was observed in 10 mandibles (59%). In two cases it was just lateral to the symphyseal line while in 7 mandibles (53.84%) it was found lateral to the symphyseal ridge occurring more on the right side. Category 1 (type a) was found only twice (15%), types (b and c) were absent as well as category V whereas category types II (a), (b) had the highest frequency of occurrence (three and four times respectively) and (c) was observed once. Categories III and IV were observed once and twice respectively.

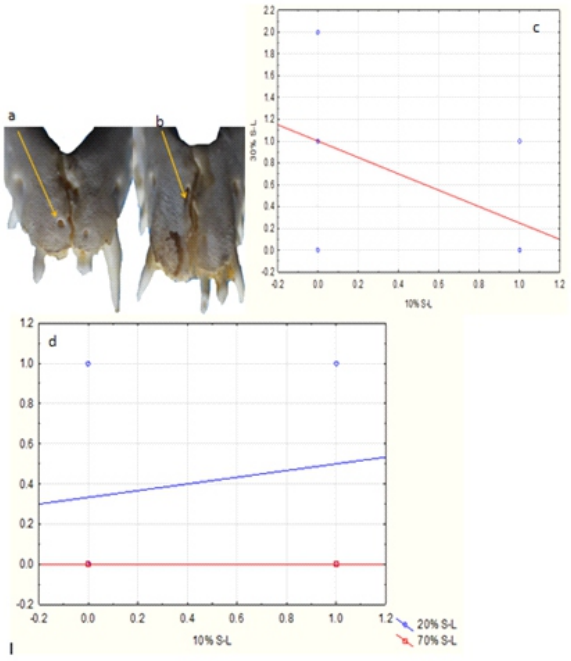


Fig. 2a, b, c, d and e. (a) Accessory symphyseal foramina lying just lateral to the symphyseal line in pups of *P.nyctereutes* (b) Infero-lateral foramen in pups (c) Position of accessory foramen in pups inferior to the symphyseal ridge in relation to the total mandible symphyseal length and (d) Histogram with fit of occurrence of accessory foramina between 20- 70% of mandible symphyseal length in pups of *P.nyctereutes* (e) Category Incidence of accessory foramina distribution in pups of *P. nyctereutes* in relation to mandible symphyseal length.

Juveniles' mandibles

Among 12 juveniles mandible examined 36 accessory foramina were found (Table I) varying from 1 (1 case) to 3 per mandible. In all mandibles (100%) at least one accessory foramen was found and was located mostly midline at about half-way mandible symphy seal length (Fig.3c and d). Mean mandibular body height and symphyseal length were 1.3±0.2cm and 2.0±0.1cm respectively.

Accessory foramina in the inferior one-third of symphysis occurred in 3 mandibles (20%), bilateral foramina lying in the lateral inferior third of the ridge were also found. Categories I c, 2b, 2c and IV type occured twice each; this made the group most widely varied.

Adults' mandibles

Average mandibular body height was 1.6±0.01cm while mean symphyseal length was 2.0±0,1cm. The total number of accessory foramina evaluated in adults was 52, the number of foramina ranged from 1 (3 mandibles) to 2 foramina in (12 mandibles). In 14 mandibles (93%) at least one accessory foramen was present on the symphyseal surface of the mandibular body and absent in 1 case. All the five category types of foramina were identified in the adult group except the subtype 1d. Categories 1 (a, b, c), II (a, b and c), III, IV and V. Category types Ia, b and c accounted for 48% of investigated foramina, those at alveolar surface level (type a) were always bilateral and never more than two in a mandible (Fig. 4a); these occurred in 2 mandibles (13%). The average position was observed as within lower third of mandibular body height and superior fifth of symphyseal length. Both midline foramina were dorsal and almost on symphyseal line (Fig. 4b) and within 0.3-0.5cm from the line (left and right. Fig. 2a). The foramen diameter ranged between 0.1- 0.8cm, single foramen located midline superior or within the ridge (type c) occurred once. Categories II (a) and (b) was observed twice each. Lateral foramina to the ridge (III) was found twice (13%) and occurring frequently

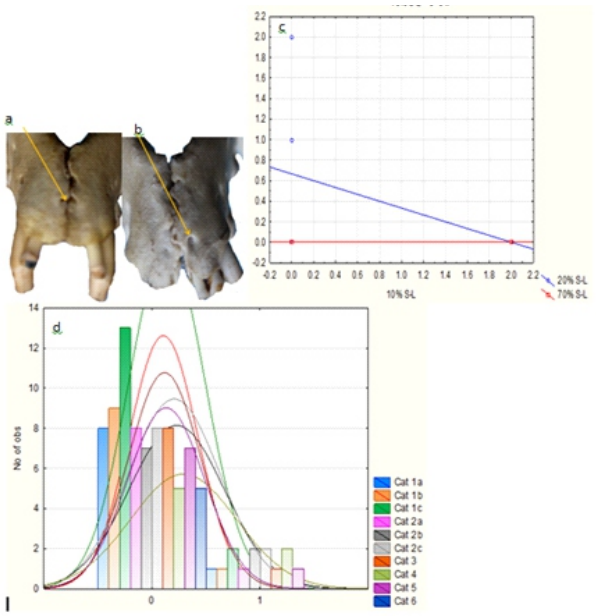
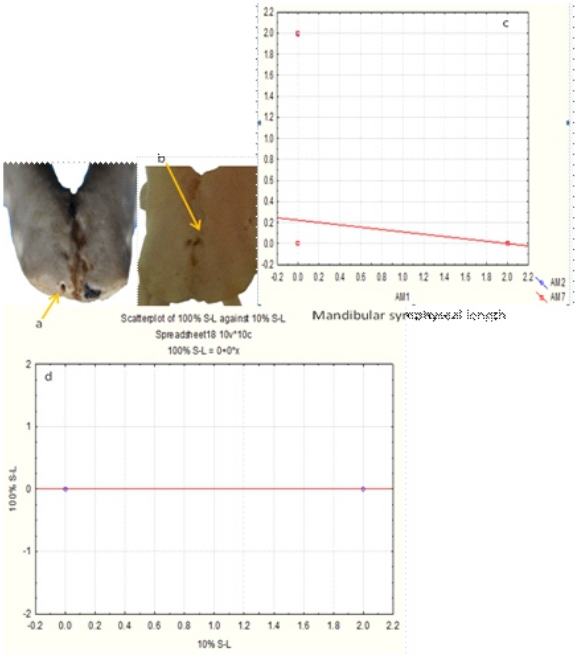


Fig. 3 a, b, c and d. (a) Midline accessory symphyseal foramina in juvenile,(b) dorso-lateral accessory foramen in *P.nyctereutes*(c)-Multiple regressions showing the concentrations of the accessory foramina at 20% of the symphyseal length and (d) Histogram showing category Incidence of accessory foramina distribution in juveniles' *P.nyctereutes* in relation to mandible symphyseal length.



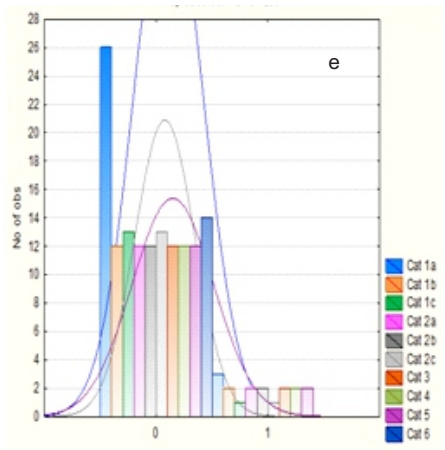


Fig.4a, b, c, d and e: Category type 1a accessory symphyseal foramina occurring at the alveolar surface in adult,(b) midline –central accessory foramen in *Procyonoides nyctereutes* (c) Position of accessory foramen supero-lateral to the symphyseal ridge in adults in relation to total mandible symphyseal length (d) Distribution graph showing position of accessory foramen inferior to the symphyseal ridge in adults in relation to total height of mandible symphyseal length (e) Histogram with fit of category distribution of occurrence of accessory foramina on the external surface body in adult *Procyonoides nyctereutes* mandibles in relation to mandible symphyseal length

DISCUSSION

Phylogeny modulates incidence, location, size and pattern of observable traits (Gruenberg, 1963). In mandibles, accessory foramen refers to all unnamed foramina aside mandibular, alveolar sockets and mental (Sutton, 1974; Murlimanju *et al.,* 1996: Gupta *et al*, 2013). Genetic classifications of the present species to the most recent evolution type (*viverrinus*) or the earlier *ussuriensis* or *procyonoides* (Makinen *et al*., 1986; Ward et al., 1987) notwithstanding, show that accessory structures are epigenetic in nature and are neither side nor sex dependent (Helle and Kauhala, 1991; Kaur *et al.,* 2012; Sisman *et al*., 2012). Several craniological studies have been conducted on various subspecies of this predator dog (Hidaka et al., 1998; Kauhala et al., 1998; Jurgelenas et al., 2007) but accessory foramina were not confirmed especially in *Nyctereutes*. *procyonoides viverrinus* (Japanese raccoons) being of a more recent evolution (Makinen, 1986 Ward and Wurster-Hill, 1989). The genus *Procyonoide scancrivorus* of tropical origin in the present study has neither been reported for detailed topographic descriptions and population variations in this regard within the subspecies. Literary evidence showed that frequency of occurrence varies between subspecies (Ellerman and Morrison-Scott, 1951; Latrov, 1971; Madeira, 1978; Kauhala *et al.,* 1998) due to evolutionary (Das and Suri, 2004; Korhonen et al., 1990), environmental and genetic (Ward and Wurster-Hill, 1989) changes explained by Robertsonian translocations (Makinen *et al,* 1986; Ward *et al.,* 1989) as occurs when new species evolve.

In this investigation, we observed the concentrations of a vast majority of foramina in the symphyseal region of mandibles and at least one in the internal surface; and this is in agreement with the findings of other authors (Baldissera *et al.,* 2002; Fanibunda and Matthews 2000; Kaufmann *et al.,* 2000; Kawai *et al.,* 2009). It's been reported in literature on lingual foramina with established channel connections with buccal accessory foramina (Hidaka *et al.,* 1998; Hatori *et al.,* 2002; Liang *et al.,* 2004). According to Bacioglu (2009) and Kawai *et al.,* (2009), the probability of the existence of an accessory mental foramen should be kept in mind in order to avoid neurovascular complications during implant placement, regional anaesthesia, surgical correction of jaw deformities and peri-apical surgery.

On the lingual surface of mental area of the mandible, nutrient foramen appears as mandibular lingual foramen; the more constant and larger diameter foramina serve as a path to a plexus of vessels and occasionally small sized nerves, branches of the sublingual artery (branch of the lingual artery), and sub-mental artery (branch of the facial artery) or branches from anastomosis formed between these vessels, penetrate the foramen reaching canals within the bone (Chapnick, 1980; Freitas et al., 1994; Mc Donnell, 1994; Vadgaonkar and Rai, 1994). Both centrifugal and centripetal blood circulation functions in periodontal and alveolar processes (Delmann, 1981; Searle, 1954a).

Accessory foramina in mandibles have been known to transmit branches of nerves supplying the roots of the teeth. Nerve block techniques failure occurs if any of these nerves or their branches passes through these accessory foramina (Olopade and Okandeji, 2010). This knowledge is therefore of importance in clinical dental procedures in captive species. The presence of such foramina might also be an alternate route for tumour spread (Vadgaonkar and Rai, 2013).

We also reported in our study that midline accessory foramina was a fairly constant feature of the mandibles cutting across the age groups with a gradual migration from mid-lateral symphyseal position found frequently more in pups to a more central symphyseal ridge observed more in adults of this species suggesting the contributions of opposing Merkel's cartilage and connections of symphysealossicles in the development of the

mandible in this area (Chavez-Lomelli *et al.,* 1966) and consistent with the findings of Shiller and Wiswell (1954); Sutton (1974) and Przystanska and Bruska (2012). The observation of variation in topographic co-locations of the evaluated foramina among age groups demonstrated late appearance and persistence in adolescent and adult ages with developmental variations of number within populations. Developmental studies on the occurrence of accessory foramina and their relation to the alveolar teeth (Chavez-Lomelli *et al.,* 1966) in fetuses explained their connections with mandibular canal and important routes for nerves and blood vessels.

Raccoon dogs *(Procyonoides nyctereutess)*, in this study exhibited the accessory symphyseal foramina phenomenon which has neither known nomenclature nor classifications (Kaur *et al.,* 2012) among populations. Dearth of information on the developmental contributions of accessory foramina in adults but which has been observed in young pups and dependent on the modeling process of embryonic stages (Chavez-Lomelli *et al.,* 1966; Onar *et al.,* 2001) has necessitated this investigation, we hypothesize that developmental processes such as interactions between canalization and developmental stability in this species may be responsible for the phenotypic variability observed in this respect and suggests a significant degree of developmental instability in the high percentage occurrence of accessory mental foramen in mandibles of the current species being evaluated (Halgrimson *et al.,* 2004).

Mandibular body studies in other species (Onar *et al.,* 2001) suggested their topographic locations depended on muscular attachments and that they are found bilaterally (Baldisera and Silviera, 2002; Fannibunda and Matthews, 2000; Hidaka *et al.,* 1998; Kauhala *et al,* 1998), the present evaluations confirmed the bilateral situation in 88% of cases.

It is therefore concluded that accessory mental foramina is a constant structure found in majority of the mandibles of the *Procyonoides nyctereutes* evaluated and can thus be classified according to position, diameter, topography and co-location into categories I-V and is of relevance in anthropologic studies, and solving taxonomic ambiguities among similar populations.

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