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Cranio-dental morphology and morphometry of the Franquet's epauletted fruit bat (*Epomops franqueti*)

Oyetunde K. Ekeolu [1]* and Ebunoluwa R. Asenuga [2]

[1] Department of Veterinary Anatomy, Faculty of Veterinary Medicine, University of Benin, Benin City, Nigeria.

[2] Department of Veterinary Physiology and Biochemistry, Faculty of Veterinary Medicine, University of Benin, Benin City, Nigeria.

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Abstract

Fruit bats are megachiroptera, which are widely distributed in Africa. They feed mainly on fruits, and are vectors for diseases. The anatomy of the cranium and dentition of the fruit bat is vital in foraging and mastication, and ultimately in the fruit bat's survival. Studies on the cranio-dental morphology and morphometry of the fruit bat are scarce. The present study evaluated the cranio-dental morphology and morphometry of the Franquet's epauletted fruit bat (*Epomops franqueti*). Fifteen *E. franqueti* were used for the study: five adult males, five adult females and five juveniles. They were captured from their natural habitat and acclimatized at the Anatomy Animal House, University of Ibadan, and were provided with fruits and portable water all through the study. They were euthanized using ketamine hydrochloride injection (25 mg/kg body weight) administered intramuscularly on the medial side of the thigh muscle. The weight of the skulls and mandibles were measured using a weighing balance, while the length of the skull and mandible, teeth height and diameter were measured using a vernier caliper and a flexible plastic meter rule. Results showed that the weight of the male and female adult skulls and mandibles as well as the length of the skull and mandible of both sexes were significantly ($p < 0.05$) different. The adult male *E. franqueti* had a significantly ($p < 0.05$) longer skull length (60.20 ± 0.23 mm) than the females (52.30 ± 0.10 mm). However, both the adult male and female *E. franqueti* had an almost equal dimension of the maxilla bearing teeth which was not significantly ($p > 0.05$) different (male – 20.00 ± 0.20 mm; female – 19.20 ± 1.8 mm). Though diet solely does not determine the pattern of bat dentition, the present study indicated that the dentition in *E. franqueti* was phylogenetically related, adapted to their diet as seen in other chiropteran species.

Keywords: Fruit bat; *Epomops franqueti*; Cranio-dental morphology and morphometry; Mandible; Maxilla; Sexual dimorphism.

*** Correspondence:** Oyetunde K. Ekeolu; Email oyetunde.ekeolu@uniben.edu; Phone: +2348054063270
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Introduction

Bats are either microchiropteran or megachiropteran, and are the only mammals that can sustain their flights (Bakwo Fils, 2010). Fruit bats belong to the suborder Megachiroptera and family Pteropodidae. The diets of fruit bats are mainly fruits, nectar from flowers and pollen (Buckles, 2015) in contrast to the microchiroptera that are carnivorous and feed mainly on insects (Voigt *et al*., 2012). Bats have been implicated in the spread of deadly viral diseases such as Ebola (Simons *et al*., 2014, Omoleke *et al*., 2016), and more recently Covid 19 (Wang *et al.,* 2021). Also, they are said to be agents for seed dispersal (Oleksy *et al*., 2017). The microchiroptera employ echolocation apparatuses unlike the megachiroptera that has well developed optic nerve and centre for vision, which are used when foraging for food (Ekeolu *et al*., 2019). The foraging ability of fruit bats does not only rely on echolocation and vision but also on their tooth pattern as it has been reported in other mammals (Clarin *et al*., 2013, Santana *et al*., 2025).

Mammalian tooth pattern is reportedly diet derived, and the tooth morphology and distribution vary across species (Popa *et al*., 2016). The teeth of bats has been the model for studying the evolutionary pattern of the mammalian teeth. Megachiroptera tooth pattern alternate between frugivory and nectarivory (Freeman, 1988). Frugivory chiropteran tooth pattern is reportedly derived from dilambdodont insectivorous tooth pattern, meanwhile *Eidolon helvum*, a fruit bat has been investigated to be diphyodont (Freeman, 1988, Popa *et al*., 2016). Within insectivorous bats, their diet types have also been reported to distinguish their cranial and mandibular size, as well as the number and size of teeth (Sadier *et al*., 2023). Insectivorous bats that feed on hard bodied insects have robust cranium and mandible, but fewer and larger teeth than is seen in insectivorous bats that prey on soft-bodied insects (Freeman, 1988).

Epomops franqueti forages on fruits such as almond (Ekeolu *et al*., 2020) and this fruit bat's teeth are adapted for piercing, extraction and suction of the fruit juice by pressing it against the hard palate (Dumont and O'Neal, 2004; Mqokeli and Downs, 2013). It has also been reported that there are intra-specific variations in the number and morphology of the teeth of fruit eating bats. Reports on this variation in the size, number and morphology of bat teeth is said to be dependent on the size and toughness of the flesh of the fruit that they eat at a given time; which then bears a relationship with the jaw and skull size of the bat (Mqokeli and Downs, 2013; Self, 2015). However, reports on tooth number, morphology and size relative to jaw and skull size with respect to its anatomy in *Epomops franqueti* is scarce. Thus, there was the need to bridge the information gap in existing literature on dentition in fruit bats such as *Eidolon helvum* (Popa *et al*., 2016) and *Epomops franqueti* where there is scanty dental documentation. The present study investigated the craniodental morphology and morphometry of the Franquet's epauletted fruit bat (*E. franqueti*) in Ibadan, Nigeria.

Materials and Methods

Fifteen *Epomops franqueti*, comprising of five adult males with shoulder epaulette, five adult females with well-developed mammary glands each, and five non-sexualized juveniles were used for this study. They were captured from their habitat in Faculty of Arts, University of Ibadan, Oyo State, Nigeria, using mist net, and were acclimatized for 48 days with adequate supply of almond fruits and potable water (Ekeolu *et al*., 2020). The bat body weight was measured using a Microvar® weighing balance (Microvar, UK). They were euthanized using ketamine hydrochloride injection given at the dose of 25 mg/kg body weight intramuscularly on the medial side of the thigh muscle. Then, the heads of the bats were processed for their skull and mandible with their teeth intact as earlier described (Ekeolu *et al.*, 2025). The weight of the skulls and mandibles were measured using Microvar® weighing balance, while the length of the skull and mandible, teeth height and diameter were measured using a Draper® 115 mm vernier caliper (Mektronics, Australia) and a flexible plastic meter rule.

All data collected were subjected to ANOVA analysis using Graph Pad prism version 11. Statistical significance was accepted at $p < 0.05$. The final results were expressed as means with the standard error of mean.

Results

Maxilla: The dorsal view of the skull of adult male and female *Epomops franqueti* presented a slightly domed skull while that of the juvenile had prominent domed shape (Figure 1). The *E. franqueti* had a heterodont type of teeth. The mean weight of the skull of the adult male *E. franqueti* was 2.224 ± 0.008 g while that of females was 1.772 ± 0.069 g. The mean weight of the skull of the juvenile *E. franqueti* was 0.7200 ± 0.011 g.

In the adult male *E. franqueti*, the maxilla had alveoli thickness of 4.01 ± 0.2 mm, while the alveoli thickness of the adult female maxilla was 3.05 ± 0.1 mm; the alveoli thickness of the juvenile maxilla was 2.02 ± 0.2 mm. The maxilla bore a small incisive bone that carried four very small homodont looking incisors (during preparation of the skull, one may lose the tiny incisors).

The mean thickness of the incisor bone in the adult male *E. franqueti* was 2.11 ± 0.1 mm, while that of the adult females was 2.13 ± 0.1 mm, and that of the juvenile *E. franqueti* was 1.01 ± 0.2 mm. For both sexes and in the juvenile, the medial incisor had a cutting edge while the lateral incisor was pointed.

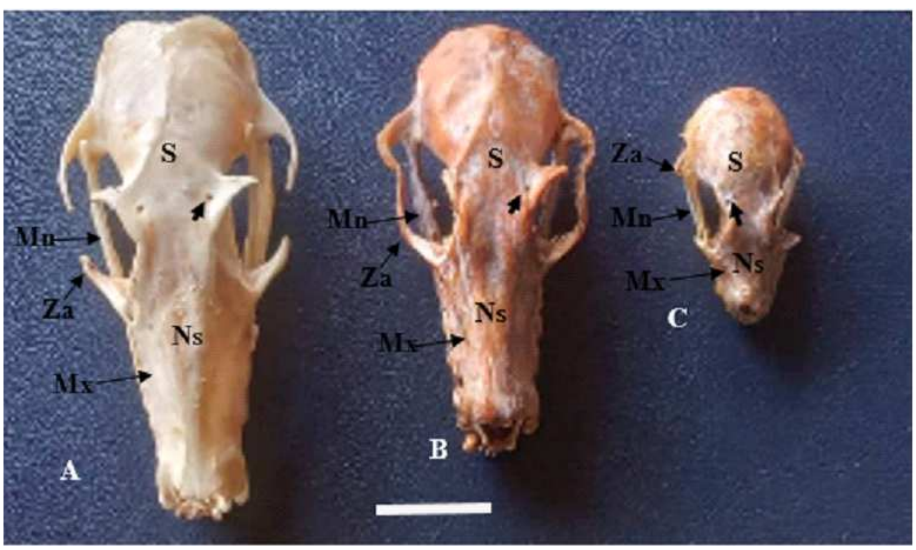

Figure 1. The dorsal view of the skull of adult male (**A**), adult female (**B**) and juvenile (**C**) *Epomops franqueti*. Observe the shape of the frontal bone (**S**) of the skull with a more flattened surface in the male, compared to the female, and the juvenile with a domed shaped. The frontal bone continues with the nasal bone (**Ns**) at the frontonasal junction, which continues ventrally with the maxilla (**Mx**). This bone constitute the upper jaw that bears the upper teeth, excluding the incissors. Black arrow points to the supraorbital foramen. Also note the zygomatic arch (**Za**) and the mandible (**Mn**). [Bar is 1.5 cm]

A big and longer upper canine tooth protruded from the maxilla with a pointed edge; it has a mean length of 10.42 ± 0.13 mm in adult males and 10.31 ± 0.03 mm in adult females. In the juvenile *E. franqueti*, its mean length was 4.5 ± 0.2 mm, with a pointed edge that was not obviously curved inwards, unlike in the adult of both sexes where it was curved inward, so that the convex surface of the tooth related to the buccal aspect.

The length of the crowns and roots in adult male *E. franqueti* were 6.25 ± 0.4 mm and 4.24 ± 0.4 mm, respectively, while that of the adult females were 5.02 ± 0.1 mm and 5.01 ± 0.1mm, respectively. The juvenile *E. franqueti* had almost even dimensions of the crown and the root as seen in the adult female, with mean values of 3.01 ± 0.2 mm and 2.01 ± 0.1 mm, respectively.

The maxilla of *E. franqueti* bore a diastema, located between the canine and the first premolar teeth. In the adult male and female *E. franqueti*, the space had a mean diameter of 4.23 ± 0.1 mm and 4.10 ± 0.2 mm, respectively. The diastema in the juvenile was not measured because it was difficult to identify the diastema in the juvenile *E. franqueti* (Figure 1).

In the adult male and female, the first premolar had a mean crown length of 4.01 ± 0.23 mm and a mean root length of 2.21 ± 0.2 mm. The first premolar tooth had a single crown but was double rooted. It had a mean crown height of 6.12 ± 0.2 mm. The root of the first premolar tooth also had a mean length of 6.12 ± 0.2 mm. The crown of the first premolar had a cusp, which the lower second premolar grind over, and had a pointed cutting edge that projected cranio-ventrally over the lower second premolar when the jaw was closed. The second premolar had the same size and features as the first premolar (Figure 2).

The molar teeth were double rooted with single crowns as observed in the premolar teeth. In the adult male *Epomops franqueti*, the maxilla bearing teeth formed about one-third the length of the skull while in both the female and the juvenile, the maxilla bearing teeth formed about half the length of the skull (Figure 3 and 4).

Mandible: The weights of the mandibles in the adult male and female *E. franqueti* were 0.8220 ± 0.011 g and 0.5000 ± 0.158 g, respectively. In the juvenile, the mean weight of the mandibles was 0.0864 ± 0.004g. The mandible had the teeth deeply rooted in its alveoli with mean height of 4.13 ± 0.2 mm in the adult male and 4.02 ± 0.1 mm in the adult female *E. franqueti.* All the four incisors on the incisive portion of the mandible had cutting edges with slight indentation on the cutting surface of the crown. The crown of the incisors had mean height of 1.12 ± 0.23 mm.

Just lateral to the incisor, on the body of the mandible was the first canine tooth. It was curved out and pointed beyond the lateral upper incisor when the jaw was closed. The mean length of the canine in the adult male was 7.21 ± 03 mm, while in the adult female, it was 7.32 ± 0.2 mm. The mean length of the canine in the juvenile *E. franqueti* was 2.24 ± 0.1 mm. The crowns and roots of the canine teeth in adult *E. franqueti* had a mean height of 3.32 ± 0.4 mm and 4.10 ± 01 m for the males, and 3.41 ± 0.2 mm and 4.30 ± 0.01 mm for the females. The juvenile crown and root heights were 1.0 ± 0.01 mm and 1.0 ± 0.01 mm, respectively. In both sexes and in the juvenile *Epomops franqueti*, a pattern of a smaller canine tooth was observed and located away from the first. In the mandible, the premolar and molar teeth had single crown and were double rooted (Figure 3).

Both maxilla and mandibular molar teeth of *E. franqueti* had mean length of 3.02 ± 0.2 mm in the adult males, except for the last molar teeth with length of 2.0 ± 0.1 mm. In the female the mean length of the molar was 3.04 ± 0.01 mm, the last molar length was 2.2 ± 0.1 mm.

The cusps for both adult male and female *E. franqueti* were stained. Also, the medial and lateral surfaces of the teeth of the adults were stained, except the lateral surfaces of the canine teeth. No part of the incisors (both upper and lower) of the adults had stains. In the juvenile however, only the lateral surfaces of the crown of all the teeth (except the canine) were stained (Figure 4).

Sixty percent of the juvenile *E. franqueti* had a sprouting second molar tooth, while in others the second molar was missing. The incisors were not stained in all the juvenile *E. franqueti*.

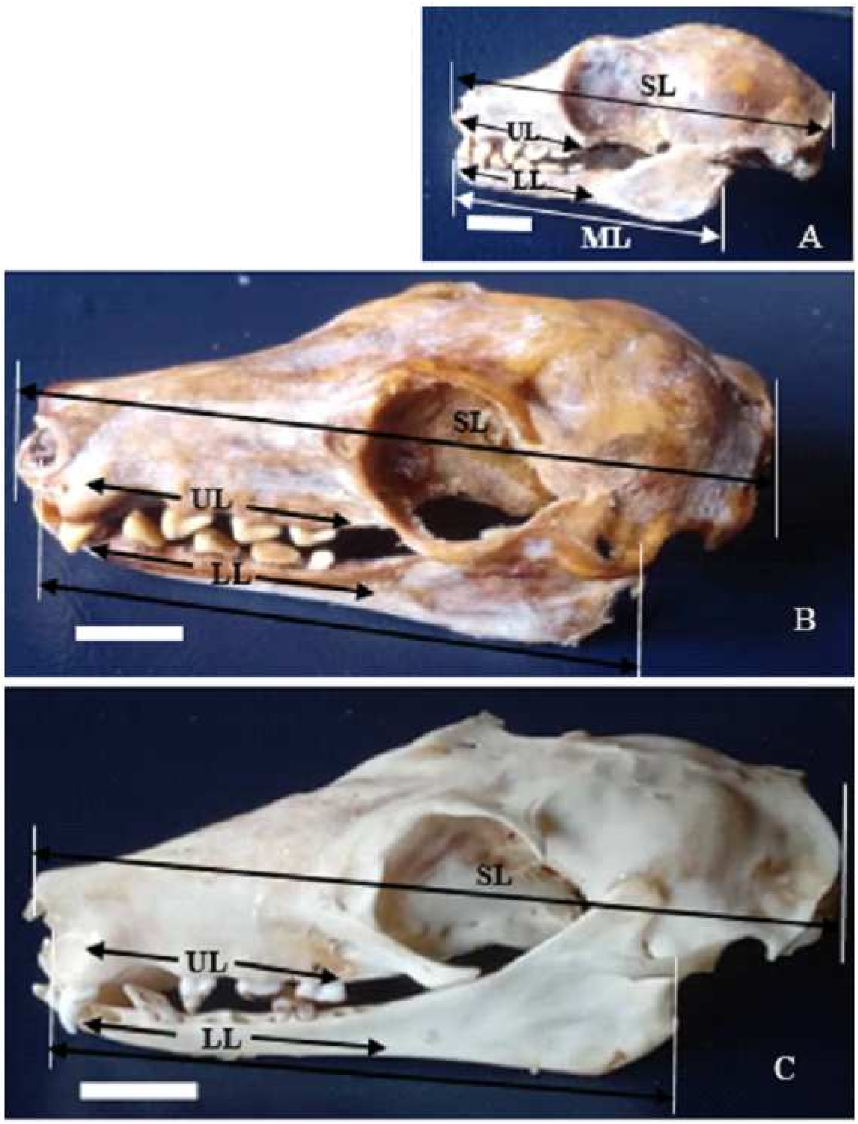

Figure 2. The skull of juvenile, (**A**) adult female (**B**) and male (**C**) *Epomops franqueti*, showing the relative measurement of the whole skull length between the most rostral and caudal parts of the skull (**SL**); length of the maxilla bearing teeth (**UL**); mandibular length (ML), measured between the rostral and caudal parts of the mandible; then the body of the ramus that bore the teeth (**LL**). The bars in (A, B, and C) were: 0.5 cm, 1.0 cm and 1.0 cm, respectively.

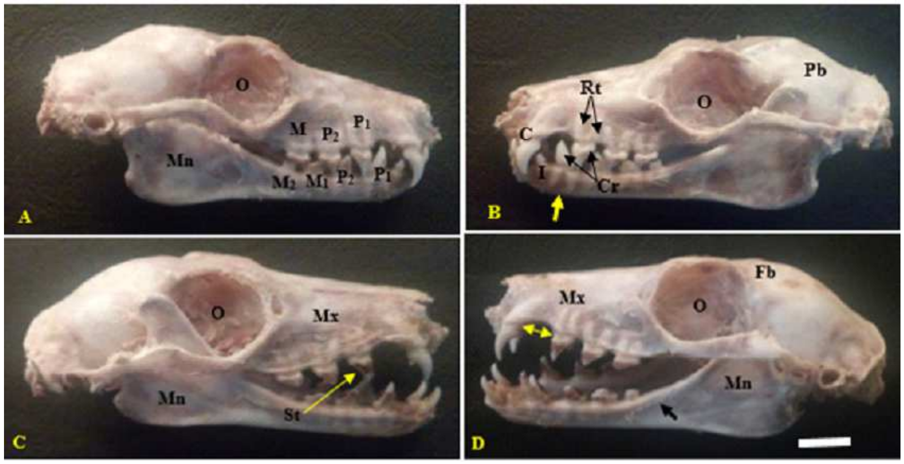

Figure 3. Adult female *Epomops franqueti* skull and mandible, showing the right and left lateral views with its dentition. Observe in (A), the upper teeth with the first premolar, second premolar and molar (**P_1, P_2** and **M**), then the lower teeth with first premolar, second premolar, first molar and second molar (**P_1, P_2** and **M_1, M_2**) on the body of the mandible (**Mn**). Note the bony orbit (**O**). In (B), observe the canine tooth (**C**) and the double roots (**Rt**) of the upper first premolar and its cutting edge (**Cr**) with that of the lower first premolar. Also, note the lower incisor tooth (**I**); the parietal bone of the skull (**Pb**). In (C), Note the stain (**St**) on the surface of the upper first premolar. In (D), black arrow points to the alveoli bone of the mandibular body. Note the diastema between the canine (**C**) and the upper first premolar teeth (**P_1**). Also note the frontal bone (**Fb**). [Bar: 1.0 cm]

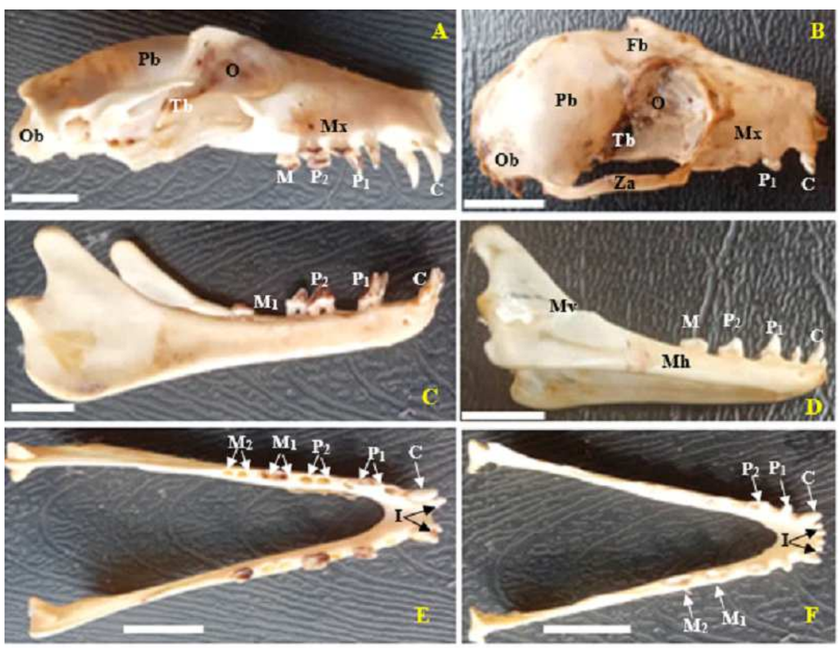

Figure 4. The skull and mandible of adult male and female *Epomops franqueti*. In (A), observe the adult male maxilla (Mx) bearing the upper teeth: Canine, first and second premolar and the molar (**C**, **P_1, P_2** and **M**). In (B), the adult female maxilla bearing the upper teeth shows the canine and first premolar (**C** and **P_1**)**.** The adult male and female lateral view of the mandible in (C and D) show the lower teeth: canine and the first, second premolar, and first molar (**C**, **P_1, P_2** and **M**)**.** However, in (E and F), the dorsal view reveal the alveoli socket for second molar (**M_2**) in addition to the (**C**, **P_1, P_2** and **M_1**) and the Incisors (**I**). [Bars in (A and B): 1.0 cm; Bar in C: 1.5 cm; Bar in D: 1.5 cm; Bars in E and F: 1.0 cm]

Sexual dimorphism: The weight of male and female adult skulls and mandibles as well as the length of skull and mandible of both sexes were significantly ($p < 0.05$) different. The adult male *Epomops franqueti* had a significantly ($p < 0.05$) longer skull length (60.20 ± 0.23 mm) than the female (52.30 ± 0.10) (Figure 2). There was no significant difference ($p > 0.05$) between the adult males (20.00 ± 0.20 mm) and females (19.20 ± 1.8 mm) in the dimension of the maxilla bearing teeth. The mean skull length in the juveniles was 25.40 ± 0.4 mm, and the maxilla teeth bearing part measured 10.40 ± 0.2 mm.

The mandibular length in the adult male (47.30 ± 0.021 mm) and female (43.20 ± 0.1 mm) *E. franqueti* did not significantly ($p > 0.05$) differ. The body part of the mandible that bore the teeth in both sexes measured 25.01 ± 0.50 mm and 24.06 ± 0.12 mm, with no significant ($p > 0.05$) difference.

The adult male *E. franqueti* had a longer length of the canine teeth than the adult female.

Discussion

The *Epomops franqueti* studied had heterodont teeth type, as the number of teeth in the juvenile corresponded to the number of teeth displayed in the adult. However, the small teeth size in the juvenile increased in the adult. The tooth size became big relative to the size of the jaws with age, except for the pin-size incisors.

The maxilla of the adult male and female *Epomops franqueti* had a pair of incisors ($I^1 I^2$), one canine (C^1) and a pair of premolars (P^1 P^2). Also, the mandible of adult male and female *Epomops franqueti* had a pair of incisors (I_1 I_2), one canine (C_1), and a pair of premolars (P_1 P_2). This is similar to what was reported earlier in *Eidolon helvum* (Popa *et al*., 2016). However, the maxilla had one molar (M^1) and the mandible had a pair of molars (M_1 M_2) unlike in the straw-colored fruit bat that reportedly had a pair of permanent molars for both upper and lower jaws (Popa *et al*., 2016).

In the *Epomops franqueti* like in many frugivorous bats the incisors remained pin-shaped, and this suggest its use in piercing fruits (Freeman, 1998). The present finding in *Epomops franqueti* of one upper molar and a pair of lower molar was similar to the report on *Haplonycteris fischeri* (Philippine pygmy fruit bat) whose dental structure does not require higher number of molar for grinding on their diet, as they feed on soft fruit (Heidemann, 1989, Giannini and Simmons, 2007). The fewer the number of molars the less the need for grinding of their food as reported in *Desmondus rotundus* (Vampire bat) (Giannini and Simmons, 2007). However, the findings in *E. franqueti* was unlike the observations reported on the *Artibeus jamaicensis*, a fruit bat in the neotropical region with three upper and lower molars (Berkovitz and Shellis, 2018) where this pattern is known to be effective in prolonged mastication on hard fruits (Esquivel *et al*., 2021), which effectively helps them chew their diet that is mainly fruits, for maximum extraction of the juice (Freeman, 1998).

The big inward curved canine teeth observed in the *Epomops franqueti* in the present study has been reported in bats, to be useful in grasping, piercing and tearing the flesh and rinds of fruits before they are directed and pressed against the hard palate for the extraction of fruit juice (Mqokeli and Downs, 2013). The canine tooth in bat may be important in the directional movement and occlusion of the food particles (Freeman, 1992). The sharp cutting edge observed in the premolar in the *Epomops franqueti* is believed to be an adaptation for cutting and piercing into fruits rather than for tearing (Dumont and O'Neal 2004).

Regarding the teeth morphology in the adult male and female *Epomops franqueti*, sexual dimorphism was not pronounced. The significant difference in the craniodental morphology of the adult male and female *Epomops franqueti* with regards to skull conformation is thought to be as a result of the fact that cranial dimension correlates with biting force (Ospina-Garcés, *et al*., 2018): the adult male *Epomops franqueti* with deeply rooted tooth that suggest toughness (Self, 2015), had a robust skull, larger in size to that of the female suggesting that the male could forage on more tough, unripen and hard fruits. This is comparable to the reports on other bats (Ramírez-Fráncel, *et al*., 2021, Nogueira, *et al*., 2009), suggesting the effective use of the large skull size and fewer but bigger teeth in this male species of bat than in the females.

Although it has been reported that diet solely does not determine the pattern of bat dentition (Esquivel *et al*., 2021), the present study on *Epomops franqueti dentition* indicated that the dentition is phylogenetically related, with adaptation to diet as seen in other chiropteran species (Freeman, 1992, Sadier *et al*., 2023, Santana and Dumont, 2009).

In conclusion, the present study showed that *E. franqueti* presented fewer number of teeth with missing upper second and third molar, and missing lower third molar (26 teeth in total) in the adult. The cranio-dental morphology and morphometry of the *E. franqueti* used for the study suggests that the Franquet's epauletted fruit bat (*Epomops franqueti*) is phylogenetically related to other soft fruit eating bat.

Conflict of Interest

The authors declare no conflict of interest.

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