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Evaluation of the Appearance of Secondary Ossification Centers and Growth Plates of Metacarpal Bones in Puppies Obtained from Koko Road Area, Sokoto State, Nigeria

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Abstract

Growth plates (physes) and secondary ossification centers of bone have proven to be a major index for skeletal maturity in developing animals. The assessment of the bones on radiograph provides information to determine the age of an animal, assess the development of the skeleton and identify growth-related abnormalities of the skeleton. This study aimed to radiographically define the order of appearance of secondary ossification centers and growth plates of metacarpals of a Nigerian local puppy. Ten apparently healthy Nigerian local puppies were examined in vivo over an 8-week period. Dorso-palmar radiographs of forelimbs focused on metacarpals were taken weekly and the secondary ossification centers and growth plates of each of the metacarpal bones were examined sequentially at weekly intervals for assessment of the time of their appearance. The appearance of secondary ossification centers and growth plates of metacarpals II – V was observed at the 4th week of life on their distal epiphyses. The primary ossification center of metacarpal I became obvious at week 5. Whereas, secondary ossification center of metacarpals I was found only at the proximal epiphyses at week 6. This study provided baseline radiographic data for defining secondary ossification centers and growth plates of Nigerian local puppies. There was uniformity in pattern and time of occurrence of ossification centers and growth plates of metacarpals II-V, which appeared earlier than metacarpals I in this canine breed.

Keywords: Growth plate, Nigerian local dog, Puppy, Metacarpal bone, Radiography,

Introduction

Growth and development of the skeleton of mammals are highly regulated events which include the development of primary and secondary centers of ossification, sequential lengthening of the long bones through the action of the physeal plates and eventually the closure of the growth plates upon reaching skeletal maturity (Oviawe *et al.*, 2018b). The radiographic sequence and timeline of the appearance of ossification centers in the dog have important roles as indicators of developmental stage in Veterinary medicine, Comparative anatomy, Orthopedics and Forensic investigations as well as for age determination purposes (Charjan *et al*., 2014). Radiography is the most available and most commonly used imaging modality to study the development of the skeleton because it is cheap, non-invasive and allows one to easily visualize bone formation, physeal structure as well as the eruption of the appearance of secondary centers of ossification as a growing animal develops (Broeck et al., 2023).

The appendicular skeleton of growing dogs develops rapidly postnatally and distal limb bones are known to have predictable ossification patterns that may be readily visualized on radiographs. Of these, the metacarpal bones are of interest because of their role in forelimb support, weight bearing and locomotion as well as in function of the digits (Sutton *et al.,* 2017). The development of the metacarpal bones occurs via endochondral ossification; a process in which a primary ossification center appears in the diaphysis followed by the appearance of secondary centers in the epiphyseal ends which fuse together to remodel and form a definitive shape single bone when skeletal maturity is reached. The radiographic appearance and closing of growth plates around these ossification centers in the metacarpals can be used to estimate the skeletal age of a growing animal (Oviawe *et al.,* 2018b).

Accurate knowledge of the normal ossification pattern is essential for discriminating normal physiological skeletal maturation from abnormal development in growing animals. In disorders of bone growth, premature physeal closure, trauma to the growth plates, congenital orthopedic diseases, nutritional osteopathies and developmental abnormalities in skeletal development are known to cause differences in ossification sequence and effect in overall limb development (Charjan *et al*., 2014). Correct interpretation of veterinary radiographs depends on adequate reference material on normal patterns of physeal development and ossification center appearance with age, especially in young dogs where seemingly subtle variations from normal growth can lead to marked changes in limb function (Oviawe *et al.,* 2018a).

Various researchers have documented the ossification patterns in different breeds of dogs using radiography and other imaging modalities (Sutton *et al.,* 2017; Wennemuth *et al.*, 2020; Roccaro *et al.*, 2021). However, differences exist among breeds because of genetic variation in body size, rate of growth, varying environmental influences and nutritional factors. Large breed dogs for example, generally mature at a slower rate than smaller breed dogs. Use of ossification tables for foreign breeds for Nigerian indigenous dog populations may not be applicable or accurate for these animals.

The Nigerian local dog represents an indigenous breed of dog that is well adapted to the different environments within Nigeria and it occupies important positions in the economy as hunting dogs, guards, and pets in both rural and urban areas (Akinyemi, 2025). Despite its importance, there is very little published information on the skeletal development and normal patterns of growth and development of the metacarpal bones in Nigerian local puppies.

The purpose of this study was to radiographically monitor the appearance of secondary centers of ossification and growth plates of the metacarpal bones of Nigerian local puppies over a period of 8 weeks. The study aimed to provide information on the patterns, sequence, timeline and to

provide base-line radiographic data on development and growth of Nigerian local puppy which may be used as references in the evaluation of skeletal maturity.

Materials and Methods

A total of ten puppies were used for the research. The puppies comprising four females and six males were obtained from three different litters after seeking consent from their owners around Koko Road Area within Sokoto South Local Area, Sokoto State, Nigeria.. The research duration was for a period of 2 months (8 weeks). At week one the puppies weighed an average of 0.34 kg, 4 puppies were placed on ventral (sternal) recumbency on a loaded cassette placed on the x-ray table (Plate I) for radiography without sedation till they were 4 weeks old because their body is not fully developed at a tender age to withstand anaesthesia, when the puppies were mildly sedated in other to immobilize them during radiography. Xylazine hydrochloride (0.2 mg/kg) was administered to achieve mild sedation. The weight of each dog was taken before each radiograph and radiographic exposures were scheduled at weekly interval for 8 weeks. The puppies were radiographed using Power mobile x-ray machine (LX-8 MOB) installed at the Veterinary Radiology Unit of Usman Danfodiyo University, Sokoto. Exposure settings of 55-60 Kvp 8-10 mAs were used for this study. The limbs of the puppies were extended and placed on the loaded cassette containing the x-ray film on the x-ray table and the beam was collimated. After taken the radiograph in the x-ray room, the cassette was taken to the dark room for identification and manual processing of the films in the processing tank after which it was allowed to air-dry. The x-ray films were viewed and interpreted by placing them on an x-ray illuminator. The weight of the puppies at the end of the study had an average of 6.7kg.

Results

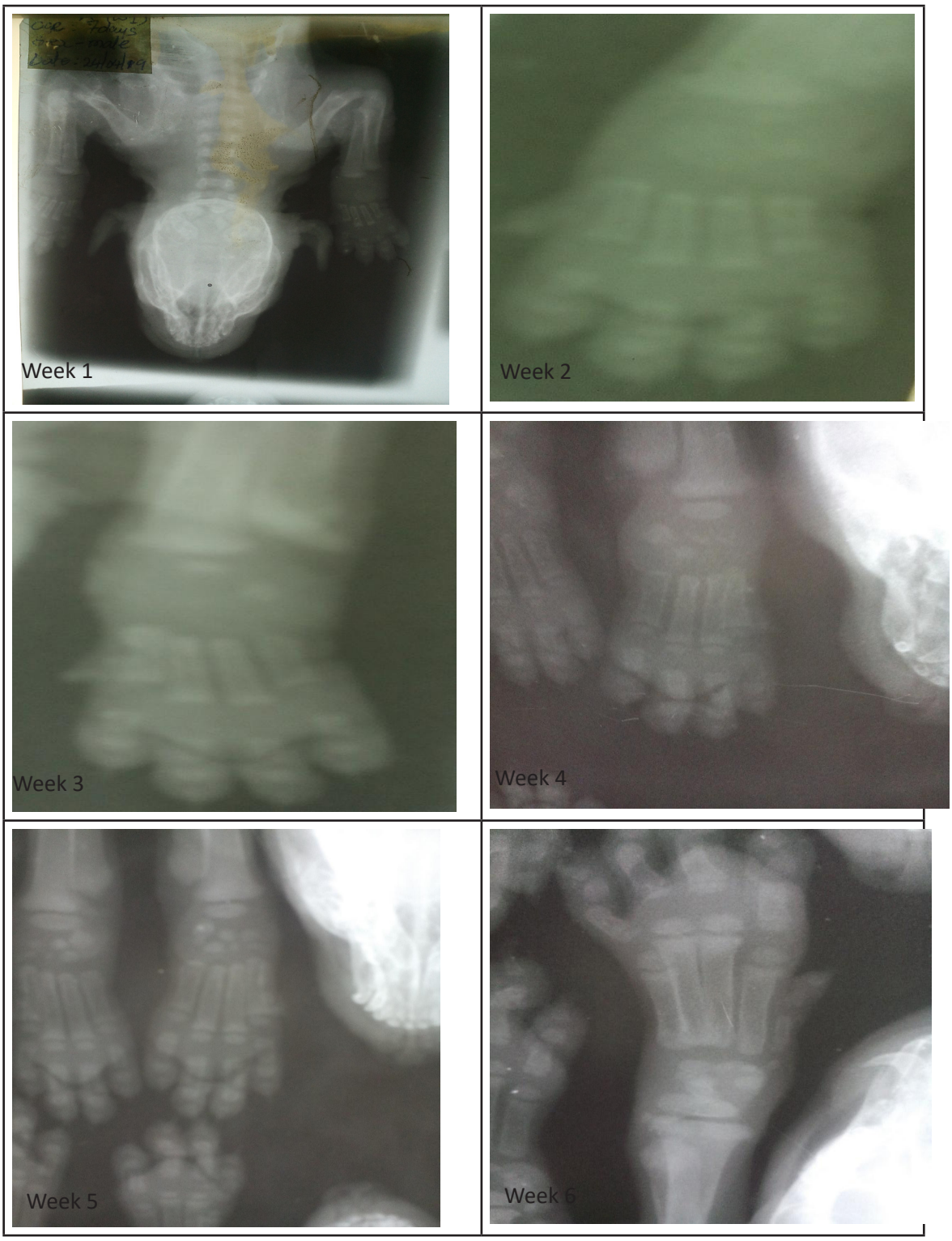
At week one, primary ossification center of metacarpal bones I-V was present with metacarpal I (Plate II) appearing very tiny. This was the same for week 2 and 3. During the period of this research, it was observed that the first appearance of the growth plate and secondary ossification center on the metacarpal bones of the dog was first observed at the distal aspect of the metacarpal II-IV at week 4. While the primary ossification center of metacarpal I became obvious at week 5. The proximal secondary ossification center and growth plate of the metacarpal 1 was observed first at week 6. The proximal secondary ossification center and growth plate of metacarpal II-V was not observed even till

the end of the study period at week 8 (Plate 2). Carpal bones were completely absent at week 1 and 2 but started developing first at week 3.

Secondary ossification centers first appeared at the distal epiphyses of metacarpals II–V at week 4, The primary ossification center of metacarpal I became more obvious at week 5. Proximal epiphyseal ossification was observed only in metacarpal I from 6 weeks onward. At week 8, no proximal secondary ossification centres or proximal growth plates observed in metacarpals II–V and no distal physis for metacarpal I in this species of animals (Table 1). This developmental sequence demonstrates a consistent pattern of metacarpal skeletal maturation in Nigerian local puppies (Plate 2).

Table 1. Weekly radiographic development of the metacarpal bones and carpal bones in Nigerian local puppies

Week	Metacarpal Bones	Carpal Bones
1	Primary ossification centres present in metacarpals I–V; metacarpal I very small. No secondary ossification (physis) centres or growth plates observed.	Absent
2	Similar to Week 1.	Absent
3	Primary ossification centres maintained; no secondary ossification centres or growth plates.	First appearance of carpal bone ossification
4	Distal secondary ossification centres and growth plates first observed in metacarpals II–V.	Developing
5	Distal secondary ossification centre and growth plate of metacarpal I became apparent.	Developing
6	Proximal secondary ossification centre and growth plate first observed in metacarpal I.	Developing
7	Continued development of all previously observed ossification centres; proximal metacarpal I ossification more distinct.	Developing
8	No proximal secondary ossification centres or proximal growth plates observed in metacarpals II–V and no distal physis for metacarpal I.	Further ossification and maturation



First part of Plate 2: Showing the presence of primary ossification centers, development of secondary ossification centers and growth plates of the metacarpal bones from week 1 to week 8.

Plate 2: Showing the presence of primary ossification centers, development of secondary ossification centers and growth plates of the metacarpal bones from week 1 to week 8.

Discussion

This study identified the radiographic timing of the onset of appearance of primary and secondary ossification centers and growth plates within the metacarpal bones of Nigerian local puppies throughout the first eight weeks of life. The patterns observed within this study support a predictable skeletal maturation sequence, providing benchmark data that can be used for age estimation, assessing skeletal maturity, and diagnosing developmental orthopaedic disorders.

The appearance of obvious primary ossification centers within metacarpals II-V at week one of the study, while being very small and rudimentary at metacarpal I, supports differing ossification timelines within the various metacarpal bones. This finding is in agreement with previously identified differences within the appearance of ossification within canine skeletal structures, where not all ossification centers appear simultaneously (Broeck *et al.,* 2023). The absence of visible secondary ossification centers and growth plates throughout the first three weeks of life may be due to a lack of mineralization of the epiphyseal cartilage at this stage making these structures radiographically undetectable regardless of developmental stage (Charjan *et al*., 2014).

The first appearance of secondary ossification centers and growth plates within the distal epiphysis of metacarpals II-V at week 4 of the study indicates the presence of rapid epiphyseal development. A similar progression has been identified within developing dogs where secondary ossification centers are visible once sufficient deposition has occurred within the epiphysis (Oviawe *et al.,* 2018b). The rapid development of the distal epiphyseal ossification centers and growth plates within metacarpals II-V is in line with the work reported by Charjan *et al*., (2014). This may be correlated to their more prominent role in supporting the weight of the growing puppy and limb movement.

Metacarpal I demonstrated a delayed maturational pattern, where a primary ossification center became more obvious at week five and a proximal secondary ossification centers appeared at week six. These later stages of metacarpal I development correlate with its diminished biomechanical sig-

nificance and anatomical appearance (Oviawe *et al.*, 2018a). The appearance of proximal secondary ossification centers for metacarpal I at week 6 is in line with the work reported by Charjan *et al*. (2014). Metacarpals II-V did not display an ossified secondary ossification center at the proximal epiphysis by week eight of the study indicating that dogs do not have a proximal secondary ossification centers and growth plates in metacarpal II-V.

No appearance of any carpal bone was observed during week one and two of the study. The carpal bones began to appear from week three onwards. The findings that carpal ossification is a postnatal process and occurs with time throughout early puppyhood as also documented by Broeck *et al.* (2023).

The present study provides the first detailed longitudinal radiographic description of metacarpal ossification and growth plate development in Nigerian local puppies. Unlike previous reports that focused mainly on exotic breeds or generalized skeletal maturation, this study establishes breed-specific developmental milestones and demonstrates the differential timing of ossification among individual metacarpal bones, particularly the delayed maturation pattern of metacarpal I. In clinical application, this information would be of value to the estimation of ages and confirmation of skeletal development in young canine, especially interpretations of pediatric radiography of appendicular skeleton.

In conclusion, the observed pattern of the onset of secondary ossification centers and growth plates within the metacarpal bones till week four, with the metacarpal II-V having only distal ossification centers without the proximal and the absence of distal secondary ossification centers in metacarpal I only the proximal secondary ossification centers even at week eight, provides valuable information regarding normal developmental skeletal patterns within Nigerian local puppies which may be used to aid the assessment of skeletal age and the diagnosis of developmental skeletal abnormalities. Further studies of longer durations are recommended to identify the time of complete physeal closure and full skeletal maturity of the metacarpal bones in Nigerian Local Dogs.

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