DENTAL ERUPTION PATTERNS AND PROFILE OF DENTAL ANOMALIES IN THE NIGERIAN INDIGENOUS PIG (*Sus scrofa*)

BY

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CERTIFICATION

I certify that this work was carried out by Dr. M.E. Okandeji, in the Department of Veterinary Anatomy, University of Ibadan, under my supervision.

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DEDICATION

This work is dedicated to my parents Mr. Roland (late) and Mrs. Adeite Okandeji**,** who did everything possible, within their means, to give us the best they could afford. I would not be here today if they had not *planted the seed*. I also dedicate it to the future generation of researchers, for whom this foundation was laid.

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ABSTRACT

Pigs are omnivores which possess two sets of teeth, the deciduous and permanent teeth. Patterns of dental eruptions have been deployed in age estimation, while variations in dental eruption reflect the influence of genetics and the environment. Dental anomalies are noticeable deviations from the normal dental architecture. Despite the advances in dental studies in exotic pigs, there is limited information on the eruption pattern and dental anomalies of the Nigerian Indigenous Pig (NIP), which are important indices in production. This study was therefore designed to investigate the pattern of dental eruption and profile of dental anomalies in the NIP.

Adult NIPs (six females, one male), with history of extensive husbandry, were obtained, housed intensively, and fed compounded feed (calcium-2.45%, crude protein-16.06%, metabolisable energy-2,659kcal/kg) supplemented with cassava peels. The pigs were allowed to mate naturally and pregnant sows were observed till farrowing. Piglets (24 males, 27 females) and subsequent adults (12 males, 14 females) were retrieved, from the initial total of 51 piglets, for deciduous and permanent teeth eruption investigations, respectively. Deciduous tooth eruption was monitored, by oral observation, thrice weekly, from day one to 24 weeks, while permanent tooth eruption was monitored from 18 to 148 weeks. The profile of dental anomalies was assessed, using 47 macerated skulls of randomly selected pigs from the eruption studies (21 males, 26 females), that were sacrificed at various time points, between 12 and 204 weeks. Data on eruption and dental anomalies were observed and data analysed using descriptive statistics and Student's *t*-test at $\alpha_{0.05}$.

All piglets had eight "needle" (third incisor and canine) teeth at birth. Females had earlier onset of eruption of deciduous teeth (3.19±0.24 weeks), compared to males (3.38±0.25 weeks), while males had earlier onset of eruption of permanent teeth (20.33±0.33 weeks), compared to females (20.64±0.25 weeks). The eruption time for the third maxillary incisor, the mandibular and maxillary canines, and the fourth mandibular premolar teeth were significantly earlier in the adult males (38.00±2.07, 41.73±1.65, 42.18±1.71 and 67.29±0.42 weeks, respectively) compared to the females (47.24±1.52, 48.75±1.61, 51.50±1.04 and 69.45±0.64 weeks, respectively). Adult pigs (69.2%) did not erupt the first mandibular premolar tooth, while the deciduous mandibular incisor tooth was persistent in 42.3%. The deciduous teeth eruption sequence in the NIPs, was $i_3/i^3 \rightarrow c_1/c^1 \rightarrow i_1 \rightarrow p_3 \rightarrow p^3 \rightarrow i^1 \rightarrow i_2 \rightarrow p_4 \rightarrow p^4 \rightarrow p^2 \rightarrow i_2 \rightarrow i^2$, while permanent teeth eruption sequence was $M_1 \rightarrow P^1 \rightarrow M^1 \rightarrow I_3 \rightarrow I^3 \rightarrow C_1 \rightarrow P_1 \rightarrow C^1 \rightarrow M_2 \rightarrow M^2 \rightarrow I_1 \rightarrow I^1 \rightarrow P_3/P^3 \rightarrow P_4/P^4 \rightarrow P^2 \rightarrow P_2 \rightarrow I_2 \rightarrow I^2 \rightarrow M_3/M^3$. Dental anomalies were significantly higher in females (96.2%) than males (66.7%). Most of the skulls had signs of dental attrition (97.8%), stained teeth (95.7%), at least a missing tooth (65.9%) and 48.9% had at least one persistent deciduous tooth. Dental calculus, tooth fracture, dental caries and tooth rotation occurred in 74.4, 46.8, 34.0 and 21.3% of the skulls, respectively.

The occurrence of needle and first molar teeth, as the first set of deciduous and permanent teeth to erupt, respectively, were established in the Nigerian indigenous pig. This is the first template for ageing in the Nigerian indigenous pigs. The preponderance of dental anomalies in the pig underscores the importance of the maintenance of dental health, for good management in this species.

Keywords: Nigerian indigenous pig, Tooth eruption, Deciduous and permanent teeth, Dental anomalies

Word count: 499

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LIST OF ABBREVIATIONS

NIP:	Nigerian Indigenous Pig
SEM:	Standard error of mean
FAO:	Food and Agricultural Organisation
CNC:	Cranial neural crest
DSP:	Dentine sialoprotein
DPP:	Dentine phosphoprotein
OPN:	Osteopontin
DMP-1:	Dentine matrix protein-1
ON:	Osteonectin
OC:	Osteocalcin
BSP:	Bone sialoprotein
PDL:	Periodontal ligament

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Pigs belong to the Suidae family and were originally placed in the order Artiodactyla, together with domestic ruminants, hippopotamuses, deer, camels and giraffes (Ruvinsky, Rothschild, Larson, & Gongora, 2011). A new classification, however, places them in the order Cetartiodactyla, which includes representatives of the former orders Artiodactyla, and Cetacea (whales and dolphins) (Ruvinsky *et al.,* 2011). Species of pigs are reported to be close to 500, and parade a wide range of phenotypes with regards to shape, colour, size, production and reproduction abilities (Rothschild, 2004; Wiener & Wilkinson, 2011; Wilkinson *et al*., 2013; Osei-Amponsah *et al*., 2017).

They are small, to medium-sized omnivores with stout bodies, thick bristled skin, large heads and short necks, small eyes, prominent ears, elongated (snout) muzzle, strong legs, with two functional and non-functional hooved digits, and a coiled or straight short tail ending in a tassel (Erik, Jean, Pierre d'Huart, & Oliver, 2011; Ruvinsky *et al.,* 2011). The snout is reinforced at the tip by a unique bone, the *os rostrum*, and a cartilaginous disc, providing enough rigidity for it to be used for rooting in search for food (Erik *et al.,* 2011). They are regarded as highly intelligent and social animals (Angier, 2009), possessing well-developed, large brains, similar to that of humans (Sauleau, Lapouble, Val-Laillet, & Malbert, 2009). Pigs are regarded to be the fourth most intelligent mammal, after great apes, dolphins and elephants, with their level of intelligence being comparable to that of a three-year-old human child. They are also believed to have advanced learning and problem-solving abilities (Erik *et al.,* 2011; Marino & Colvin, 2016).

Pigs have been established as an important livestock to man, primarily, as a source of protein to consumers, and a source of income to the farmer. They have high fecundity, with the possibility of farrowing two or more litters per year, thus making them good sources of experimental lines, ahead of other farm animals (Adeola, Oseni, & Omitogun, 2013). They have a fast growth rate, with short generational interval, high production potential, high adaptability to various environmental conditions, and are able to convert feed and food waste to meat and other by-products (Olopade & Okandeji, 2010; Adeola *et al.,* 2013; Borkotoky, Perumal, Singh, & Vigyan, 2014). Pigs are regarded as important research models, as they share a semblance with humans in the area of anatomy, embryology and physiology. They have also been developed as viable disease models (Ruvinsky *et al.,* 2011; Larsen & Rolin, 2004; Rothschild, 2004; Vodicka, Smetana, Ourednik, & Ourednik, 2005; Swindle, Makin, Herron, Clubb Jr, & Frazier, 2012).

They are good models for biomedical and pharmacology-related studies (Larsen & Rolin, 2004; Wang, Liu, Fang, & Shi, 2007; Stembırek, Kyllar, Putnova, & Buchtova, 2012). Studies involving wound healing and drug absorption have been conducted on the mucous membrane of their mouth (Campisi *et al.*, 2008; Larjava & Perio, 2011). Pigs have also been adopted as study models in periodontal stem cell application (Sonoyama *et al*., 2006), dental implants (Nkenke *et al*., 2005), periodontal tissue regeneration (Ding *et al*., 2010) and studies on teeth and jaw bones regeneration (Wang *et al.,* 2007). They are also regarded as unique models for tooth replacement studies, because they possess diphyodont dentition, like what obtains in humans (Wang *et al*., 2014), and a viable source of xenotransplantation (Ruvinsky *et al.,* 2011).

A tooth is a hard white structure positioned on vertebrate jaws. Teeth are adaptations of bony dermal plates found in ancestral fishes (Sharpe, 2001; Chen *et al*., 2020), and are composed of materials of varying density and thickness (enamel, dentine, and cementum). These materials enclose a pulp-filled cavity, that contains bundles of nerves and blood vessels (Papagerakis & Mitsiadis, 2013). Teeth are formed inside the jaws and their emergence is an intricate process, characterised by a step-by-step movement within bony tissues and the gum, to their functional sites in the mouth (Okandeji, Lijoka, Atiba, Adebiyi & Olopade, 2023a). In species with two groups of teeth, the emergence of the latter group is heralded by the breakdown and exfoliation of the roots belonging to the former. As a localised activity within both jaw bones, tooth eruption displays accurate chronology and bilaterally symmetrical process involving the breakdown and establishment of bony tissue on the opposing side of the emerging tooth (Kjær, 2014).

Mammalian teeth are essential tools for mastication, and in higher animals, including humans, they partake in sound production (phonation) and the protection of other vital structures within the oral cavity. Species-specific adaptations and differences however exist, depending on the variety of nutrition, specific for each species (Ungar, 2015; Agrawal & Rai, 2016; Pineda-munoz, Lazagabaster, Alroy, & Evans, 2017). In contrast to the rest of the tissues in the body, they are believed to possess the capacity to withstand the effects of nutritional and growth-related stress and are therefore suitable intra- and inter-species growth markers. Dental eruption patterns are useful in ageing and determining the effects of genetics and the environment, on manifestation of intra- and inter-species differences (Setchell & Wickings, 2004; Tucker & Widowski, 2009).

Pigs are omnivores, which have a diphyodont, heterodont, and brachydont dentition, with the exception of the tusk (canine tooth) of the boar. The boar canine teeth are believed to have elodont, aradicular and hypsodont characteristics (Smith, Rao, & Rawlinson, 2020). The deciduous (primary, temporary) dentition (arrangement of teeth) of domestic pigs comprises 28 teeth: 2(incisor$^3/_3$, canine$^1/_1$, premolar$^3/_3$, molar$^0/_0$). The third maxillary (upper) and mandibular (lower) incisor teeth, and canine teeth are present in the oral cavities of new born piglets at birth, and are usually substituted by a permanent (secondary) set of teeth, 2(Incisor$^3/_3$, Canine$^1/_1$, Premolar$^4/_4$, Molar$^3/_3$), bringing the total permanent teeth to 44 (Tucker & Widowski, 2009; Stembırek *et al.*, 2012)

Dental anomalies can be described as observable variations from the normal dental architecture (Karjodkar, Mali, Sontakke, Sansare, & Patil, 2012). In animals, they are frequently due to taming or captivity, occurring in the course of the growth and development of dental structures (Penzhorn, 1984). Incidences of some anomalies appear to be greater in domesticated animals, than those in the wild. This may be attributed to the influences of inbreeding, an overall decrease in the skull length and effects of artificial selection (Horwitz & Davidovitz, 1992; Feldhamer & McCann, 2004; Zinoviev, 2010; Binois, Bridault, Pion, & Ducrocq, 2014). Developmental conditions may be influenced inherently by aberrations in the differentiation and formation of the teeth laminae, buds, and tissues, or may be environmentally induced by trauma, microbial irritations, and chemical, which result in variations in the sum, size, and shape of affected teeth (Pavlica, Erjavec, & Petelin, 2001). Nonetheless, it might be challenging to establish the factors responsible for each abnormality (Horwitz & Davidovitz, 1992).

The mouth is the doorway to the gastrointestinal system, therefore any aberration, disturbance or dysfunction within the oral cavity may result in adverse consequences on affected animals (Okandeji *et al*., 2023a). Thus, it is imperative to identify the dental anomalies that affect pigs and how they are similar or different between breeds, as anomalies of the oral cavity do not only instigate distress in affected animals, they may also trigger the onset of systemic conditions (Kyllar & Witter, 2005; Olusa, 2014; Yurdakul *et al*., 2018).

The deciduous and permanent teeth eruption patterns of many pig breeds have been described, which include Large Whites (Tonge & McCance, 1973), the miniature pigs (Weaver, Jump, & McKean, 1966, 1969; Wang *et al.,* 2007), Yorkshire pigs (Tucker & Widowski, 2009), and European wild pigs (*Sus scrofa*) (Matschke, 1967). Similarly, many reports have described the dental anomalies in feral and domesticated pigs (Horwitz & Davidovitz, 1992; Feldhamer & McCann, 2004; Zinoviev, 2010; Binois *et al.,* 2014; Malmsten, Dalin, & Pettersson, 2015; Malmsten, Lundeheim, & Dalin, 2020; Smith *et al.,* 2020).

However, information on the patterns of tooth eruption and profile of dental anomalies in the Nigerian indigenous pig (NIP) appears to be scarce. This research work was therefore conceived to investigate, record and report the pattern of eruption of the deciduous and permanent teeth, along with the profile of dental anomalies in the NIP, in order to provide reference data on this pig breed.

1.2 PROBLEM STATEMENT

Unlike in other indigenous and exotic breeds of pigs, the patterns of tooth eruption and the profile of dental anomalies in the Nigerian indigenous pigs have not been reported, neither have they been related to their production performances. Dental eruption patterns are useful in ageing and ascertaining the effects of genetics and the environment, on manifestation of intra- and inter-species differences, it is, therefore, imperative to identify the factors that might disturb tooth eruption, and identify the types of disorders or anomalies that are present in pigs, the vulnerable age groups, the prevalence of such anomalies, as well as the factors that may influence such disorders or anomalies.

1.3 AIMS AND OBJECTIVES

This study was designed to investigate the patterns of dental eruption and the profile of dental anomalies in the Nigerian indigenous pig.

Objectively, this work seeks:

(i) To establish the deciduous teeth eruption pattern (Sequence and timing) in the Nigerian indigenous pig.

(ii) To establish the permanent teeth eruption pattern (Sequence and timing) in the Nigerian indigenous pig.

(iii) To identify the presence or absence of sexual dimorphism in the eruption patterns in the Nigerian indigenous pig.

(iv) To profile, and record the prevalence of dental anomalies, and identify sex and age-related differences of these anomalies in the Nigerian indigenous pig.

1.4 JUSTIFICATION

Information on the patterns of eruption of deciduous and permanent teeth, and the dental anomalies of the Nigerian indigenous pig, appears to be unavailable. Since little is known about the tooth eruption patterns and dental anomalies of this breed of pigs, it is imperative to distinguish if there are similarities or differences in the eruption patterns and dental anomalies profile between this breed and those available in literature. Data generated will provide information on the dental eruption pattern (timing and sequence) in the NIP, which will be useful in age estimation in this breed of pigs and the scheduling of dental treatments or interventions. Data generate can also be used to provide information on the relationship between genetic and environmental factors as it relates to dental eruption and dental anomalies in the NIP.

CHAPTER TWO

LITERATURE REVIEW

2.1 TAXONOMY OF PIGS

Table 2.1: Overview of the taxonomy of pigs

Kingdom	Animalia
Subkingdom	Bilateria
Infrakingdom	Deuterostomia
Phylum	Chordata
Subphylum	Vertebrata
Infraphylum	Gnathostomata
Superclass	Tetrapoda
Class	Mammalia
Subclass	Theria
Infraclass	Eutheria
Order	Artiodactyla
Suborder	Suina
Family	Suidae
Subfamily	Suinae
Genus	Sus
Species	Scrofa

(Myers *et al*., 2022).

Members of the Suidae family are also called pigs or hogs, and include non-ruminant, even-toed ungulates species. The family Suidae is wide and is made up of six genera with 18 or 19 known species, with several species living in South-East Asia. Some species are located in what is referred to as Eurasia while many are present only in Africa (Ruvinsky *et al.*, 2011). The genus Sus is the most common and the species *Sus scrofa* is the most widespread, having 9 extant species and 12 extinct species (Erik *et al.*, 2011). The surviving member of the Suidae family is made up of about 15 varieties classified into several genera: Sus (domestic and wild pigs) from Eurasia; Porcula (pygmy hogs) from Northern India and Babyrousa (babirusa) from the Island of Sulawesi. Others include Potamochoerus (Bush pig and Red river hog), Phacochoerus (common and desert warthogs) and Hylochoerus (Forest hog) from the sub-Sahara of Africa (Ruvinsky *et al.,* 2011).

2.2 EVOLUTION AND HISTORY OF PIGS

The study of mammalian evolution is contingent on having an adequate knowledge of the evolution of teeth and the interaction between tooth shape and diet (Evans, Wilson, Fortelius, & Jernvall, 2007). Although originally placed in the mammalian order Artiodactyla, along with other even-toed ungulates (Ruvinsky *et al.,* 2011), pigs are now thought to fit into the Order Cetartiodactyla, including the previous Orders Artiodactyla and Cetacea (Ruvinsky *et al.,* 2011).

At the beginning of evolutionary development, pigs and pig-like mammals were separated from ruminants in the early stages of evolution (some 35 million years ago) of the order Artiodactyla (Erik *et al*., 2011). The evidence of their early divergence is seen in a range of attributes that distinguish them from other artiodactyls. These attributes include their short-crowned teeth with separated and rounded apex, in comparison to what obtains in other artiodactyls; possession of 4 unique digits; and the possession of a simple stomach (Erik *et al.,* 2011).

The pig is regarded as one of the earliest domestic animals and many varieties are believed to have originated from wild hogs of Eurasia (*Sus scrofa*). Prehistoric proofs from the Middle East suggest that pigs were tamed as far back as nine thousand years ago, with the rearing of many domestic animals by nomads, as pigs are suggestive of a stable farming population. About 16 subspecies of the wild pig were reported to be common around Europe, Asia and Africa (Northwest) (Weka, Bwala, Adedeji, Ifende, Davou, Ogo, & Luka, 2021).

From the perspective of history and science, domestic pigs are believed to have evolved from wild pigs of Eurasia (*Sus scrofa*). This data has been applied by many researchers to authenticate the origin of several European and Asian breeds of pig (Giuffra, Kijas, Amarger, Carlborg, Jeon, & Andersson, 2000). However, available evidence suggests that domestic pigs from Asia do not share the same pedigree with the domestic pigs from Europe (Weka *et al.,* 2021).

2.3 GENERAL CHARACTERISTICS OF PIGS

Pigs have varying body sizes. The Pygmy hog (*Porcula salvania*) varies in length from 58–66 cm and weighs between 6–9 kg whereas the Forest and Eurasian wild pigs have lengths of 130–210 cm and weigh 130–275kg. Pigs generally possess big heads, small necks and eyeballs, and conspicuous pinnae. They are characteristically plump, with bristle coats, and short tails ending in tassels. Male pigs are associated with spiral penises, which match corresponding grooves in the female cervices (Erik *et al.*, 2011).

Pigs are easily identifiable with the presence of an elongated snout that has a disc-shaped tip; a morphological adaptation linked to soil rooting. The nostrils are terminal and moveable. They are positioned to enable pigs sniff out potentially edible substances, and can be closed to prevent soil or such food substances from being inhaled into the nasal pathways. The rostral end of the snout is flat and reinforced by a cartilaginous structure called the *os rostrum*, which also aids in rooting of soil for edible items (Erik *et al.*, 2011).

Their teeth reflect the nature of their diet. Pigs are omnivores with two sets of dentition (Smith *et al.,* 2020) and majority of them possess the maxillary incisor teeth, which are absent in many artiodactyls. However, the Desert Warthog (*Phacochoerus aethiopicus*) is an exception, having no maxillary incisor teeth. Pigs have only a short diastema, placed between the third incisor and the first premolar teeth on the lower jaw, where present. Inter-species variation of teeth number exists (Erik *et al.,* 2011), but the generally accepted dental formula is 2[I 3/3, C 1/1, P 4/4, M 3/3 = 44 (Matschke, 1967; Tucker & Widowski, 2009).

In the existing Suborder Suina, *Sus species* and relatively, the *Phacochoerus species* are largely widespread in the appearance of their separate and rounded teeth cusps (bunodont), retention of many teeth, and possession of simple digestive systems, and appendages. *Sus and Porcular species* have distinctive qualities of the canine teeth in common. The maxillary canine teeth on the upper jaw are rounded and three-sided in appearance, being bigger in male pigs than in female pigs, with their teeth sockets (alveoli) pointing upwards and outwards. Maxillary canine teeth stay rasped at the pointed ends because they are usually sharpened, through continuous contact, by the mandibular canine teeth, as against only at the rostral faces. As a result, the canines can grow without restraints, pointing upwards, outwards and backwards, as observed in *Hylochoerus*, *Phacochoerus*, and several non-existent genera (Erik *et al.,* 2011).

Pigs can survive in a variety of environmental and climatic conditions because they have the ability to adapt to nearly all ecological conditions. All species of pig wallow in muddy or clean water to help to cool down their body temperatures. The mud crusts also shield them from flies and insects bites, and blood-sucking arthropods, which are often displaced when they rub their skins against hard objects, including rocks and trees (Erik *et al.,* 2011).

They are able to commune with themselves via their senses of smell, sight and sound. Their sensitivity to olfactory cues is comparable with what obtains in dogs, and they use scent to discriminate and identify individuals, and to find hidden food substances (Croney, Adams, Washington, & Stricklin, 2003). Their emotions and moods are often expressed by how they raise their hairs, position their ears, tails, and arch their backs. They also express a variation of phonations, with as many as 20 various vocal expressions (Reimert, Bolhuis, Kemp, & Rodenburg, 2013).

Pigs are naturally very hygienic animals. They are known to select areas for defecation and urination, which are usually different from where they feed and sleep unless there isn’t enough space in their pens (Stolba & Wood-Gush, 1989; PBS, 1996). Domestic female pigs can attain sexual maturity as early as 5 months (Reiland, 1978), while boars make vocalizations and release pheromones in their saliva and urine to attract females in oestrus (McGlone, Aviles-Rosa, Archer, Wilson, Jones, Matthews, Gonzakez, & Reyes, 2021). Wild and domestic pigs have a gestation period that ranges between 90-158 days. New born piglets are usually well developed at birth but are susceptible to cold weathers (Fraser, 1980). They establish a teat order which involves choosing and maintaining a particular teat on the mammary gland, for feeding, throughout the period of suckling. Lactating sows can also act as foster sows for piglets from other sows (Wallenbeck, Rydhmer, & Thodberg, 2008).

2.4 POPULATION OF PIGS

Pigs are the fourth most populous mammals on earth after humans, cattle, and sheep. As at October, 2021, world pig population was estimated to be close to 750 million (USDA, 2022), with China having almost 50% of that population (Shahbandeh, 2022).

2.5 BREEDS OF PIGS

More than 100 breeds and approximately 230 breeds of pigs have been recognised worldwide. It is believed that many breeds, located in various parts of the world, have not been fully identified or classified. Common breeds available in Nigeria are Nigerian Indigenous breed, Large white (Yorkshire), Large black, Landrace, Durock, and Hampshire.

2.5.1 Large White (Yorkshire)

This docile breed originated from the Yorkshire County, in England. Yorkshires are white with long, stout body and erect ears. Dark pigmented areas (freckles) may be present on the skin (Gillespie & Flanders, 2010). Yorkshire sows are highly prolific, with a litter size of 8-12 piglets, and they have good mothering ability. Their live adult weights range from 250-450kg, for both sexes (Roy, 2022).

2.5.2 Large Black

This docile British breed is hardy, and considered to be appropriate for extensive husbandry management (Ekarius, 2008). Large blacks are black, with long robust body and large droopy ears. They are prolific, farrowing about 8-13 piglets per litter (Alderson, 2001). Their live adult weights range from 270-320kg for both sexes (Roy, 2022).

2.5.3 Duroc

This breed is golden brown in colour, with floppy ears. Duroc sows are very prolific, having a litter size of about nine piglets. They are known for possessing outstanding siring abilities. The average live weight is 300kg for males and 250kg for females (FAO, 2009).

2.5.4 Landrace

This Danish breed is white, long, and full-bodied, with large droopy ears. Landrace sows have good mothering abilities and can farrow as many as 11 piglets. Their adult live weight ranges from 250-400kg for both sexes (FAO, 2009).

2.5.5 Hampshire

Hampshire pigs are usually black in colour, having white bands around the shoulders and the legs. They possess straight pinnae and muscular bodies. Owing to these features, the male Hampshire pigs are regarded as suitable sources of viable offspring. As a result,

Hampshire boars make good sires. Sows have a litter size of about nine piglets. The average adult live weight is 300kg for males and 250kg for females (FAO, 2009).
Other breeds of pigs available in the world include:

2.5.6 Hereford

Hereford breed originated from the United States of America, as the product of crosses between Duroc, Chester White, and Poland China (Gillespie & Flanders, 2010). They are hardy and docile, and are similar to the Hereford breed of cattle, as they have red-coloured bodies with white faces (Buchanan & Stalder, 2011). Adult weight is 270 for sows and 360kg for boars (Porter, Alderson, Hall, & Sponenberg, 2016).

2.5.7 Mieshan

A black body, small limbs, large belly, and an unattractive look are characteristic of this China breed. They are highly prolific with a litter size of 14-17. A mature boar weighs as much as 450 kg while a mature sow weighs about 350 kg, on the average. (FAO, 2009).

2.5.8 Tamworth

This breed of pig, although developed in England, has an Irish origin. It has a long narrow body with varying shades of red skin colour, an elongated skull (head) and rostrum, upright pinnae, and a straight facial appearance (Gillespie & Flanders, 2010). An adult male can weigh between 245-265 kg, while an adult female can weigh between 200-300 kg. Litter size is smaller, compared to other marketable varieties (FAO, 2009).

2.6 HISTORY OF PIGS IN AFRICA

The history of local pigs in Africa has elicited previous debates (Blench, 2000). It is however believed to have originated after the arrival of pigs of European and Asian origins that were introduced via commercial trading activities. This belief was boosted through genetic researches on the local pig populations in Africa. These studies showed that pig types from Western and Northern Africa possess a major European pedigree, which could be traced to the Portuguese adventure of the 15th century (Weka *et al.,* 2021). It has also been postulated that modern day pigs from East Africa could have originated from either a direct genetic transfer from breeds from the far East or from an intermediate of European origin (Weka *et al.,* 2021).

2.6.1 Pig Population in Africa

In 1998, the African top four pig populations were Nigeria (4,800,000), South Africa (1,540,000), Uganda (1,500,000) and Cameroon (1,350,000). However, reports show that this population has increased. It is estimated that there are over 40 million pigs in Africa, with Nigeria having an estimate of more than 7,500,000 pigs; Uganda, 2,700,000 and Angola, 2,600,000, amongst others (Weka *et al.,* 2021).

2.6.2 Breeds of Pigs in Africa

The genealogy of domestic pigs in Africa is unclear and greatly debatable due to insufficient prehistoric and genetic data to offer dependable postulations on the factors surrounding their origin. Although *Sus scrofa*, the ancestor of domestic pig in Africa, is believed to be indigenous to Northern Africa, its reach spreads along the Atlantic coast all the way to Rio de Oro. The breeds from the Maghreb (Western and Central North Africa) is also called *Sus scrofa barbarous*, while the one from the Sahara is also called *Sus scrofa sahariensis* (Weka *et al.,* 2021).

Sus scrofa is regarded as the ancestor of African household pigs, however, the genomic variety of breeds from Africa, coupled with the association amongst the household pigs and their predecessor (*Sus scrofa*) still remains unclarified or inadequately investigated like the foreign breeds (Amills, Clop, Ramírez, and Pérez-Enciso, 2010). The African wild pigs have been reported to have no genomic involvement, via reproduction, to the external features or characteristics of the household pigs in Africa (Weka *et al.,* 2021).

Similarly, the resolution of the genetic framework of breeds of the African pig showed an obvious variance between the West and East African breeds. The West African pigs had alleles in common with those from Europe, just as pigs from South and East Africa had genetic materials in common with Far Eastern breeds (Weka *et al.,* 2021).

The chronicle of sub-Sahara Africa pigs showed evidence of distortion arising from import of several breeds of European origin into many parts of the African continent through several routes, leading to a mixed genetic heritage of present-day African pig population. In addition, the history and spread of the porcine species in Africa has been significantly influenced by the evolution and ascendancy of Islam in some areas of the African continent, resulting in the reduction in the number of pigs from a large region of Africa (Amills, Ramírez, Galman-Omitogun, & Clop, 2013).

Local African pigs are found in all regions of Africa apart from North Africa. They are basically the same in countries where they are found and are identified by several nomenclatures including: South African Kolbroek; Malian Somo; Gabonese Bakosi; Ghanaian Ashanti Dwarf pig; Togolese Bush pig; the Nigerian Indigenous (local) pig, and the Zimbabwean Mukota pigs (AU-IBAR, 2015).

Local pig types are exclusive to the environment they are resident in and may retain genetic physiognomies which could make certain features available for future pig types that may be strategic for their existence. These characteristics, among others, are the ability to adapt to unfavourable environmental conditions, the ability to resist diseases, as well as adaptations to unfavourable systems of production in developing nations (Penrith, Thomson, Bastos, Phiri, Lubisi, Du Plessis, Macome, Pinto, Botha, & Esterhuysen, 2004; Oluwole & Omitogun, 2009). The unique characteristics of these indigenous or local pigs are however vanishing because they cannot match the rate of rapid growth and development of foreign pigs, and due to the reduction of their genetic makeup, arising from the haphazard mating that takes place between exotic and local breed types. In addition, impoverishment, insufficient information on the qualities of indigenous pigs and vague governmental plans, are also identified as part of the factors that are responsible for the gradual reduction in the population of local pigs (Weka *et al.,* 2021).

2.6.2.1 South African indigenous pigs

Two local pigs have been recognised in South Africa and they are the “Kolbroek” and “Windsnyer”. However, a third type of local pigs called the “South African hard-footed pigs” has been described. They are free ranging scavengers and can feed on and convert household and farm wastes (Weka *et al.,* 2021).

2.6.2.1.1 The South African “Kolbroek” breed

The “Kolbroek” pigs are petite pigs, with pointed ears, small snout and a flattened facial appearance. They have dark black or brown coat colours, and are usually streaked at birth (Fig. 2.1). They are also passive, with the ability to resist diseases, and survive well on feeds rich in fibre (Swart, 2010; Weka *et al.,* 2021).

Figure 2.1:The South African "Kolbroek" breed (Weka *et al.,* 2021).

2.6.2.1.2 The South African “Windsnyer” breed

The name “Windsnyer” (wind-cutter) is derived from its narrow-bodied shape. The Windsnyer pigs are smaller than the Koelboek breeds, with hairs that take the shape of unique curls. They have a variation in colour coats, and they possess elongated snouts and straight backs (Fig. 2.2). The pig is very hardy and forages for food, being able to survive periods of insufficient food supply. This breed of pig has the ability to maximize nutrient-poor food effectively (Swart, 2010; Weka *et al.*, 2021).

Figure 2.2: The South African “Windsyner pig breed (Weka *et al.,* 2021).

2.6.2.1.3 The Namibian Indigenous Pigs

The origin of the Namibian indigenous pigs is uncertain. They are common in the North of Namibia and other regions, but they are presumed to have originated from regions around the Mediterranean. These pigs have somewhat lean and elongated bodies, with elongated rostrum (Fig. 2.3). The colour of their coats varies. They can survive in tough environmental conditions and require minimal level of maintenance. They also have high reproductive potentials and are great producers of lard (Swart, 2010).

Figure 2.3: Indigenous Namibian pig with elongated rostrum (Swart, 2010).

2.6.2.1.4 The Botswanan Indigenous Pigs

The indigenous Botswanan pig is very common in the region of Tswana, South of the country. Its predominant coat colour is black and can survive the weather conditions of the country (Thutwa, Chabo, Nsoso, Mareko, Kgwatalala, & Owusu-Sekyere, 2020).

2.6.2.1.5 Mozambican Indigenous Pig (MOZ)

These pigs have black skin colour, long bristles, and elongated slim rostrum, with conspicuous mane (Fig. 2.4). Smaller populations of these pigs have spotted skin colours. Majority of them possess white legs while a smaller number also have irregularly-shaped white belt-like patch around the dorsum. They are strong and muscular, which appears to make them relatively bigger than the remaining Mozambican pigs that are mainly black in colour. The position and orientation of the pinnae vary and the eyes and mane vary in colour and level of development, respectively (Penrith *et al.,* 2004; Swart, 2010).

Figure 2.4: Black-coloured pig of Mozambique (Swart, 2010).

2.6.2.2 East African Indigenous Pigs

East African local pigs are well-built pigs, having light to dark coloured coats, white or black long legs, elongated slender snouts and established tuft of hairs (Weka *et al.*, 2021).

2.6.2.3 West African Indigenous Pigs

Synonyms of indigenous pigs in Western Africa include the West African dwarf pig or the Nigerian Indigenous pig (Nigeria), Ghanaian Ashanti dwarf pig, and the Togolese bush pig. Phenotypically, these pigs are said to have concave-shaped heads, black-coloured coats, upright or straight ears which can be swept back, and a petite cylinder-shaped snout (Fig. 2.5). They also possess short foreheads and have erect tails, with unique tuft of hairs on the dorsum (AU-IBAR, 2015). They are tough, and can thrive under inadequate husbandry practices. They usually rummage for their food, being able to utilise food or feed particles with high fibre contents. They can withstand high body temperatures and unpleasant environments. They are resistant to several indigenous parasitic infections and other disease conditions (Oluwole & Omitogun, 2009; Weka *et al.*, 2021). They are also good mothers, farrowing about 5–7 piglets. An adult local pig can weigh as much as 60kg (AU-IBAR, 2015; Osei-Amponsah *et al.*, 2017; Weka *et al.*, 2021). Nigerian indigenous pigs are still regarded as a local or an unimproved breed because of inadequate classification and characterization (AU-IBAR, 2015).

Figure 2.5. West African indigenous boar (Dotche *et al.,* 2020).

2.7 ANATOMY OF THE PORCINE HEAD

Pigs have bulbous heads with relatively elongated snouts, short necks, comparatively small eyeballs and conspicuous pinnae. The head and neck have a conical appearance, with the base blending with the trunk around the region of the fore limbs. The dorsal surface of the head is typically concave in shape, with variations ranging from slightly concave, in breeds with elongated skulls, to being markedly concave, as seen in breeds with short skulls. This gives the high caudal part of the skull an unusual projection. The porcine neck is remarkably reduced in length, thus positioning the mandibular angle close to the scapulo-humeral joint; an arrangement that limits the ability of the pig to turn its head to a large degree (Dyce, Sack & Wensing, 2002).

The most remarkable feature of the head is the rostrum or snout. It is reinforced at the tip by a unique bone, the *os rostrum*, and a cartilaginous disc. The lips are short and firm; the dorsal being indented, which accommodates the canine teeth (tusks) that projects from the lateral surface of the maxilla, regardless of the size of each tooth (Dyce *et al.,* 2002).

2.8 OVERVIEW OF DENTITION

The mammalian dentition is composed of series or set of teeth, with individual tooth having a unique shape and appearance, well modified for its specific chewing action (Papagerakis & Mitsiadis, 2013). Teeth are firm, white structures positioned on vertebrate jaws, within the mouth, used for performing masticatory activities (Chen *et al.,* 2020). They are found in almost all vertebrates and have been significantly utilized as models in scientific investigations relating to developmental modelling, signaling and evolution (Jernvall & Thesleff, 2012). Dentition is a vital part of an animal's body and information regarding its development can be harnessed in the field of dentistry and orthodontics, as well as in the field of anthropology, endocrinology, nutrition, and forensic odontology (Demirjian, 1986). It performs a strategic function in the understanding of mammalian evolution and the process of development. The distinctive attributes of dentition provide helpful information as regards the dietary and social habits of individual animal species (Sachdev, Souza, Chettiankandy, Sardar, Pakhmode, & D'Souza, 2020).

2.9 DENTAL ERUPTION

Although dental eruption is described as the clinical emergence of a tooth, through the gingiva, into the oral cavity (Suri, Gagari, Eleni, & Vastardis, 2004; Tucker & Widowski, 2009), it is actually the progressive, upward migration of the dental bud, from its developmental site within the jaw bone, further into the plane of occlusion, in the mouth (Demirjian, 1986; Srinath, Srinath, Vishwanath, & Singh, 2013; Jain & Rathee, 2022).). Tooth eruption is an intricate developmental journey, involving the well-timed cellular activity and interface of enamel organ, dental follicle, and osteoclasts and osteoblasts (Wise, Frazier-Bowers & D'Souza, 2002). It is thought to be part of complex events that occur in the head as the development and emergence of many teeth usually occur during the active phase of craniofacial development (Kardos, 1996). Tooth eruption requires the reabsorption of alveolar bone covering the crown of the tooth, leading to the formation of an eruption pathway, and the initiation of biological processes which result in the movement of the tooth through this pathway, for eventual emergence in the mouth (Srinath *et al.*, 2013; Kjær, 2014; Jain & Rathee, 2022).

2.9.1 Formation and development of teeth

Odontogenesis is described as the embryonic development of the teeth within the jaws, leading to their emergence in the mouth. It is the intricate progression whereby mineralized dental tissues arise from germ cells and give rise to ameloblasts (which produce the enamel), odontoblasts (which secrete the dentine), and cementoblasts (that produce the cementum) (Papagerakis & Mitsiadis, 2013; Datta *et al.*, 2020). It depends upon a sequence of mutual inductive communication between two neighbouring tissues, epithelial and mesenchymal tissues. The mesenchyme which partakes in development of a tooth gives rise to cranial neural crest (CNC) cells, which are located at the boundary between the ectoderm and the extreme dorsal surface of the neural tube. They move massively, to occupy the branchial arches. (Papagerakis & Mitsiadis, 2013; Datta *et al.*, 2020). Enamel organ stems from the propagation of cells in dental lamina and divides into 4 layers: the outer enamel epithelial layer, star-shaped reticular layer, the intermediate layer, and the epithelial layer of the inner enamel. Cyto-differentiation of odontoblastic and ameloblastic germ cells, which give rise to the enamel and dentine, commences at the apex of future coronal cusps. Dental histo-morphogenesis and cyto-differentiation are influenced by an alternate alteration of informative signals disseminating between epithelial cells and ecto-mesenchymal cells (Datta *et al.*, 2020).

The enamel has an epithelial origin while the dentine and cementum arise from mesenchymal precursors. While the harder and whiter enamel is found on the crown of each tooth, the greater part of the tooth is composed of the yellow dentine. The cementum, however, accumulates only in the region of the root of dentine matrix that has just been mineralized. The tooth is firmly attached to its alveolar space by a special tissue; the periodontal ligament (PDL). The PDL is located around the roots of each tooth and attaches it to the alveolar bone, by special collagen fibers (Papagerakis & Mitsiadis, 2013).

With regards to morphology, the development of a tooth commences with a thickened oral epithelial layer, eventually forming a structure called the dental lamina (Zhang, Chen, Song, Liu, & Chen, 2005; Papagerakis & Mitsiadis, 2013). In the dental lamina, cell proliferation and invagination of mesenchymal tissues in specific points commences, leading to the formation of dental placodes (they determine the positions of teeth on the jaw). Dental developmental events progress via several phases which require successive mutual exchanges and communication between the oral epithelial layer and the CNC-derived mesenchymal layer. Certain substances (signaling molecules) coordinate the several pathways of initial dental development by influencing several steps involved in the process. These substances also exert their influences as the developing tooth undergoes the different steps involved in its development. These steps are coordinated based on timed mechanisms, thus the production of the coordinating substances at inappropriate periods results in an aberration of the different steps involved in dental development, including increase in cell number, cell differentiation and cell death, which ultimately impacts on the development and the shape of the tooth (Papagerakis & Mitsiadis, 2013).

2.9.2 Formation of dental mineralized tissues

2.9.2.1 Dentine

During the initiation of tooth development, cells of the dental pulp begin to differentiate into precursor cells (odontoblasts) at the dento-enamel junction (DEJ). Immature precursor cells (odontoblasts) are columnar-shaped and produce a ground substance abundant in collage type I and vesicles. This matrix is called pre-dentine. The accretion of pre-dentine results in the breakdown of the basal lamina that relates to the epithelium of the inner part of the enamel, which is succeeded by an up-regulation of the development and release of metalloproteinase 20 (Mmp-20) and other proteins, that are found in the matrix of the enamel. Dentine, a tough elastic tissue, is characterised by the presence of penetrating odontoblast tubules that go from the dental tissue pulp to the surface (Papagerakis & Mitsiadis, 2013; Jain & Rathee, 2022).

Before root eruption, primary dentine makes up the majority of the tooth and it is made up of peritubular or intra-tubular dentine (forms the dentinal tubular wall); inter-tubular dentine; mantle dentine (initial pre-dentine located inside the tooth and lacks tubules); and circum-pulpal dentine (the innermost strata of the dentine surrounding the outermost wall of the pulp) (Papagerakis & Mitsiadis, 2013).

Odontoblasts release proteins that are related to the tooth, including dentine sialoprotein (DSP) dentine phosphoprotein (DPP), and dentine glycoprotein (DGP), coded for by one gene called dentine sialophosphoprotein (DSP) (Yamakoshi, Hu, Fukae, Zhang, & Simmer, 2005). Nonetheless, the bulk of the dentine is made up of proteins that are similar to what is found in bones. They include type I, III, and V collagens, bone sialoprotein (BSP), osteopontin (OPN), dentine matrix protein-1 (DMP-1), osteocalcin (OC), and osteonectin (ON) (Papagerakis & Mitsiadis, 2013). There is continuous, gradual deposition of dentine, despite the fact that the tooth has emerged and the root has been formed. This dentine may be the secondary type, whose deposition is regular or the inconsistently deposited tertiary type, in reaction to dental wear or disease (Papagerakis & Mitsiadis, 2013).

2.9.2.2 Enamel

The enamel of the tooth is regarded as the mammalian tissue with the highest mineral content. A fully developed enamel tissue is composed of below 1% of organic material, devoid of cells and collagen fibres. It develops in an extracellular environment covered by precursor cells called ameloblasts (Simmer & Fincham, 1995). Enamel mineral is primarily made up of calcium hydroxyapatite, with a unique proportions and arrangement of its crystals. These crystals measure about 25 nm in thickness and 65 nm in width, and are thought to extend as far as the tooth surface, from the dento-enamel junction (Papagerakis & Mitsiadis, 2013).

At the time of enamel secretion, the deposition of the matrix of the enamel is made possible by secretory ameloblasts and pre-ameloblasts. The differentiation of ameloblast commences around the tooth germ cusps, where there is a differentiation of the primary epithelial cells to pre-ameloblasts. The odontoblasts that were freshly differentiated often initiate the differentiation of ameloblast (Sasaki & Garant, 1996). Thereafter, secretory ameloblasts begin the deposition of prismatic enamel. At the time of secretion, ameloblasts secrete mostly ameloglastin, enamelin and amelogenin. These proteins, which are specific for the enamel, initiate the elongation of enamel crystals which are made up of calcium hydroxyapatite. As ameloblasts produce enamel-specific proteins and extend the bands of minerals, they withdraw from the surface of the subsisting enamel, resulting in an increase in the width of the area around the enamel. While collagen-based mineralisation processes occur in 2 steps (mineralisation of the matrix occurs after organic ground substance secretion), production and mineralisation of the enamel proceeds in just one stage (Papagerakis & Mitsiadis, 2013; Jain & Rathee, 2022).

Amelogenesis is typified by a phase of maturation, when matrix minerals are wholly laid down around the crystals. During this phase stage, the ameloblasts make available, the required area for a sustained increase in mineral volume through the gradual removal of proteins that are continually broken-down by proteases specific for each stage. Maturation-stage ameloblasts produce and bring together a special basal lamina which firmly secures the ameloblasts to the surface of the enamel tissues, ensuring that they are properly mineralised. Genes, transcription, and growth factors, as well as hormones required for the mineralisation of the enamel are also released by ameloblasts present at the maturation and transition stages (Papagerakis & Mitsiadis, 2013).

2.9.2.3 Cementum and periodontal ligament

The dental follicles (DF) appear as pouches of loose connective tissues which delineate the growing teeth from their alveolar spaces. These follicles are vital for the emergence of teeth and they transform into the periodontal ligaments (PDLs) after the emergence. The cementum is a mineralized tissue, with no blood vessels or nerve, found on the entire root surface. It possesses similar ultrastructural properties with bone and it is the interface between the periodontal ligament and the dentine, participating in the repair and regeneration of periodontal tissue post-injury (Papagerakis & Mitsiadis, 2013; Gorski & Marks, 1992; Rathee & Jain, 2021).

Cementum is originally laid down on freshly mineralised ground substance of the dentine of the tooth root, by cells that develop from the follicle of dental tissues and/or by the epithelial to mesenchymal conversion of root sheath epithelial cells. Two forms of cementum have been identified embryologically; the initial (primary) acellular cementum, (develops gradually, as the tooth emerges), and the resultant (secondary) cementum, formed after the tooth-to-tooth contact. A rapidly deposited cementum contains cementocytes, which look like osteocytes (Papagerakis & Mitsiadis, 2013).

In the course of the development of the teeth roots, dental follicles become structured into the periodontal ligaments that assist the teeth, provide nourishment and perception of pressure, and permits normal movements of the teeth. This ligament stands out amongst the numerous ligaments and tendons in the body because it is the only body tissue to traverse two separate firms structures; the dental root cementum and the alveolar bone (Papagerakis & Mitsiadis, 2013). Functional teeth are networked to one another, to the gingivae, and to the bones supporting the teeth, with the aid of periodontal ligaments, made up of types I and III collagen fibres. The principal fibres of the ligament undergo regular adaptive remodeling and they are incorporated lateral to the roots of individual tooth inside the dental bone and the cementum (Papagerakis & Mitsiadis, 2013).

The collagen fibres of the PDL are classified based on their direction and position along the tooth. Periodontal ligament fibres injury can lead to ankylosis of the tooth, making the tooth give up its capability to express uninterrupted eruption. Traumatic dental conditions, including subluxation, result in periodontal ligament fibres tear leading to painful masticatory activities. “Periodontitis” refers to the damage (pathological) to tissues of the periodontium as a consequence of inflammation. This condition may ultimately result in tooth loss or extraction, since the affected tooth lacks adequate supporting tissue (Papagerakis & Mitsiadis, 2013).

The alveolar bone is regarded as a constituent of tissues of periodontal origin and provides a means of attachment of the tooth to the alveoli while also accommodating masticatory forces. Precursor cells needed for dental bone development are located in the periosteal region, surrounding capillaries or in the periodontal ligament. Marrows from alveolar bones are viable sources of precursor cells, because they possess osteogenic potentials, similar to the ones obtained from the iliac crest. Periosteal tissues are also regarded as viable sources of cells for bone tissue renewal (Papagerakis & Mitsiadis, 2013).

As the permanent teeth emerge, the alveolar bone diminishes to permit their migration. At the same time, the development of the roots, takes place and the crown moves through the mucosa of the oral cavity that participates in the formation of a constriction made of epithelial cells on the enamel near the boundary between the root and crown. Permanent teeth cementum goes through minimal remodelling, but the surface of dental bone is constantly being resorbed and formed. This ensures the movement of the tooth, as a reaction to eruptive, growth drifting, or changing functional forces. Just after the development of their roots, roots of deciduous teeth are resorbed (Papagerakis & Mitsiadis, 2013).

2.9.3 Stages of tooth development

Early tooth development can be separated into four key stages: commencement or initiation, structural development (morphogenesis), delineation of the cells of different types of teeth (differentiation), and the production of matrices for the enamel and the dentine (Järvinen, 2008; Rathee & Jain, 2021). Further observation of dental development shows that it progresses through a series of well-defined stages: epithelial thickening or dental lamina stage, bud stage, cap stage, bell stage and maturation or eruption stage (Järvinen, 2008; Rathee & Jain, 2021).

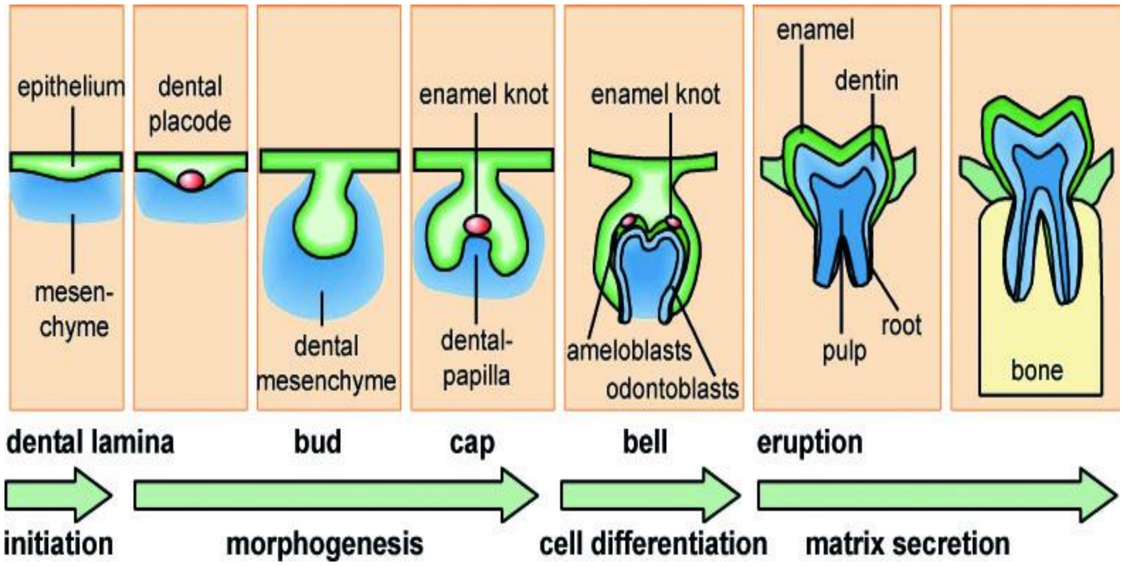

Figure 2.6: Stages of tooth development (Järvinen, 2008).

2.9.3.1 Initiation stage

In this stage, there is distinction between the dental lamina and the lamina of the vestibule, which is considered to be one of the earliest indicators of tooth development. The dental lamina links the growing tooth to the oral epithelium, for a considerable length of time. Secondary dental lamina sprouts from the primary dental lamina (Wang *et al.,* 2014).

2.9.3.2 Bud stage

This stage is characterised by the growth of the apex of the secondary dental lamina, with the condensation of the neighbouring mesenchyme. At some point in this stage, the epithelium of dental invaginates into the dental mesenchymal tissues, which surround the epithelium, forming a bud in the process (Zhang *et al*., 2005; Jernvall & Thesleff, 2012; Wang *et al.,* 2014).

2.9.3.3 Cap stage

The earliest indications of cellular organisation in the tooth bud occur at this stage. The characteristic feature of this stage is the enamel organ which appears with a primary enamel knot and is made up of three recognisable constituents which are the epithelium of the inner enamel, star-shaped reticulum, and the epithelium of the outer enamel. There is an extension of epithelial tissues into the tissues of the mesenchyme, enveloping the mesenchymal condensation in the process (Jernvall & Thesleff, 2012; Wang *et al.*, 2014).

2.9.3.4 Bell stage

This stage of dental development is characterised by both morphological and histological differentiation of the developing tooth. The dental organ appears dome-shaped and most of its cells have stellate appearance (star-shaped reticulum). It is divided into an early and a late or advanced stage. During the bell stage, the pattern of the cusps of each species develops. In species with teeth having only one cusp, primary enamel knots initially appear at the cap stage and results in the formation of the crown's apex; while in mammals with more than one tooth cusps, the positions of the future cusps are occupied by knots of secondary enamel. The bell stage is also characterised by the manifestation of stratum intermedium in the enamel organ (Jernvall & Thesleff, 2012; Wang *et al.,* 2014).

2.9.3.5 The secretory stage

This stage is characterised by final development and production of the matrix. In the course of this phase, the epithelial layer of the inner enamel becomes enamel-producing precursor cells (ameloblasts), and the neighbouring mesenchymal cells become dentine-secreting precursors (odontoblasts) (Jernvall & Thesleff, 2012).

2.9.4 Apoptosis in odontogenesis

Apoptosis, also referred to as programmed cell death, is considered to be an essential component of several biological events. These include regular cell turnover, accurate developmental and functional activities of the immune system, hormone-dependent atrophy, development of an embryo, as well as chemically-induced cell death. It is the primary process of the physiological elimination of cells, thus performing a key function in tissue regulation in normal physiological mechanisms, including throughout the stages of tooth development (Matalova, Svandova, & Tucker, 2012; Bali, Chandra, & Verma, 2013).

A fragile equilibrium involving apoptosis and viability of cells has been reported in the course of the development of the epithelial layer of the oral cavity. It has also been established that the interplay between mesenchymal and epithelial cells is very important as epithelial-mesenchymal interactions play essential roles in controlling the cells that live or die. Apoptosis is not just an unplanned occurrence, controlling only the sizes of tooth precursors, it is also involved in morphogenetic changes and the removal of specific cells (Bali *et al.*, 2013).

Apoptotic activities have numerous responsibilities, during development of the teeth. It has been identified as being present at the onset of the development and formation of the teeth, to the point where the root is completely developed. Apoptotic activities have also been implicated in early morphogenetic developmental processes, just as it has been observed when hard tissues are being formed and when teeth are erupting (Matalova *et al.*, 2012; Abramyan, Geetha-Loganathan, Šulcová, & Buchtová, 2021). It has also been associated with the growth of dental tissues buds during the early stages of dental development (Bali *et al.*, 2013).

The most crucial functions of dental-related apoptosis are the obliteration of the signal transduction of the enamel knots, the removal of rudimentary dental germ layers, as well as the morphological arrangement of ameloblasts (Matalova *et al.*, 2012)

In early bud stage, programmed cells are present in the growing epithelial layer in the oral cavity. These programmed cells gather on the dental bud when the germinal cells stay longer during the late stage of budding (Bali *et al.*, 2013). They are however, not seen in mesenchymal tissues (Bali *et al.*, 2013; Abramyan, *et al.*, 2021).

In the cap stage, clusters of programmed cells are found in enamel knots. As dental maturity progresses, these knots show no signs of a reduction in the cell sizes, signifying a swift substitution by proliferating cells encircling the enamel knots. As the initial knots disappear, apoptosis becomes less evident, but it is still identifiable in the gubernaculum (epithelium joining the enamel organ to the oral epithelium). At the cap stage, some apoptotic cells are noticeable in the mesenchymal condensation, but appear not to have any restricted pattern (Bali *et al.*, 2013; Abramyan, *et al.*, 2021).

At the bell stage, programmed cell death is observable in resultant enamel knots, in cells of the intermediate layer next to the enamel knots, and neighbouring connective tissue layer. Every tooth type navigates through similar stages of development and is made of similar materials (Bali *et al.*, 2013; Abramyan, *et al.*, 2021).

2.9.5 The role of Apoptosis in tooth development

Several functions have been suggested for programmed cell death in the development of dental including:

a) Taking part in the disturbance of the dental lamina.
b) Occurring in the main epithelial cells that invaginate at some point in bud stage.
c) Apoptosis is known to partake in the determination of the final position and size of teeth within the jaws.
d) Averts the fusion of teeth in locations without teeth via the obstruction of excessive development of dental epithelium.
e) Helps to determine the eventual teeth number.
f) Apoptosis is also involved in the machinery that helps to model the crowns of teeth (Bali *et al.*, 2013; Abramyan, *et al.*, 2021).

2.9.6 Tooth eruption in mammals

Tooth eruption is regarded as an important event necessary for the continued existence of many species (Kardos, 1996). The sequence of tooth eruption or emergence is regarded as the orderly pattern by which the teeth appear, through the gingiva, into the mouth (Setchell & Wickings, 2004; Tucker & Widowski, 2009). In mammals, tooth eruption is basically divided into 3 stages. The first stage, recognised as the phase of deciduous teeth development, is characterized by the presence of only temporary teeth in the oral cavity. The moment a permanent tooth emerges within the mouth, the teeth are in a transitional stage and the dentition is described as being mixed. Once the final temporary tooth falls off, from the oral cavity (exfoliation), the teeth present and the dentition in the mouth are referred to as being permanent (Weaver *et al*., 1969; Ravinthar & Gurunathan, 2020; Tafti & Clark, 2021).

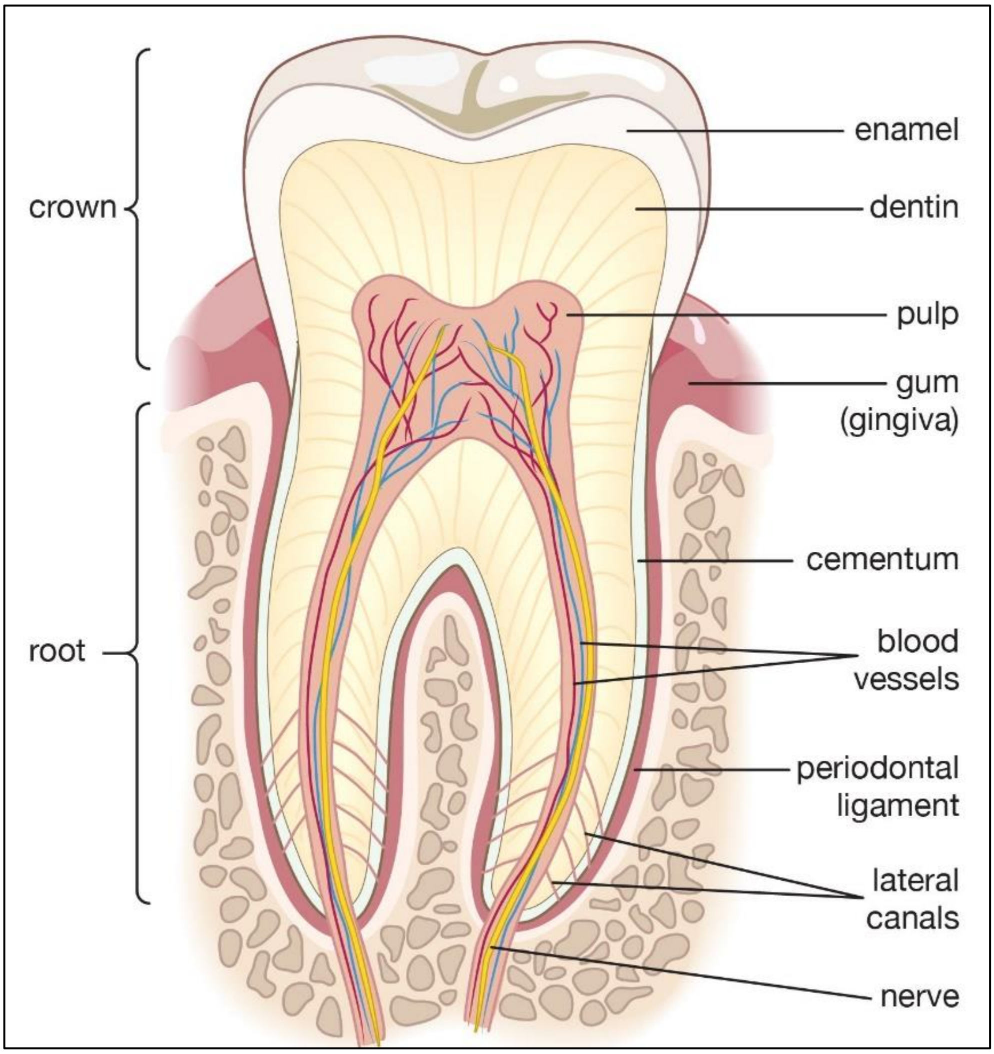

Figure 2.7: Longitudinal (schematic) section of a tooth (Britannica, 2023).

2.9.7 Stages of tooth eruption

Descriptively, tooth eruption may be classified into two parts, depending on the relationship between the tooth and alveolar bone, into intraosseous and supraosseous parts (Gorski & Marks, 1992; Jain & Rathee, 2022).

Intraosseous eruption refers to tooth eruption activities that take place within bony crypts in the jaw (Gorski & Marks, 1992). This stage entails the resorption of bony tissues to create a route for eruption and inter-radicular formation of bone, root growth, and apposition of bone, all of which aid the advancement of the emerging tooth into the route of eruption (Gorski & Marks, 1992; Jain & Rathee, 2022). The aforementioned occurrences are controlled by the dental follicle which creates areas of initiating and controlling the formation of bone, areas of initiating and controlling resorption of bones, as well as neutral regions (Marks & Schroeder, 1996; Kjær, 2014). Eruption activities are regarded as being independent of the actions of the periodontal ligament (PDL) (Gorski & Marks, 1992).

Supraosseous eruption, on the other hand, refers to tooth eruption activities, from the time the crown progresses past the alveolar crest to its functional position within the mouth. Eruption activities are possibly facilitated by the periodontal ligament (Gorski & Marks, 1992; Jain & Rathee, 2022).

Although teeth eruptions are regarded as the translocation of teeth from their developmental positions in the dental bone to their physiological positions within the mouth (Demirjian, 1986), growing teeth experience three dimensional movements, with changes in sizes within the dental bone, prior to arriving at their final anatomical positions (Marks & Schroeder, 1996). Therefore, the processes or stages of teeth eruptions may be appropriately separated into 5 phases: pre-eruptive activities, intra-osseous eruptive phase, mucosal penetration, pre-occlusal eruptive phase, and post-occlusal eruptive phase (Fig. 2.8) (Marks & Schroeder, 1996; Peedikayil, 2011; Jain & Rathee, 2022).

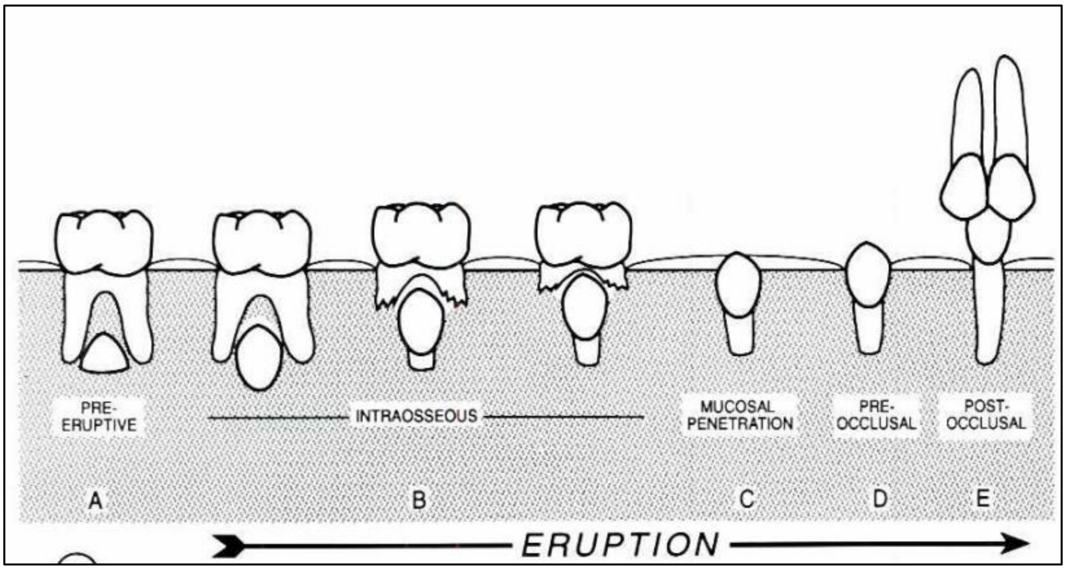

Figure 2.8: Diagrammatic representation of tooth eruption of the human first permanent mandibular premolar (Marks, Gorski and Wise, 1995).

In the pre-eruptive phase (A), the crown of the developing tooth is located in a bony crypt. Eruptive activity is believed to commence after the completion of the formation of the crown. The first evidence of this period is a region of bone resorption over the cusp tip. The intraosseous phase (B) is characterised by the commencement of root formation. The tooth relocates into an eruption route made possible by bone and tooth resorption (in deciduous dentition). After the loss of the deciduous tooth or otherwise, the emerging tooth penetrates the mucosal epithelium of the oral cavity (C) and the eruptive activities becomes rapid, with the erupting tooth moving into the pre-occlusal phase (D), until occlusal contact is made with the opposing teeth (E) (Marks *et al*., 1995).

Mucosal penetration, pre-occlusal and post-occlusal phases of tooth eruption are characteristic of the supraosseous stage of tooth eruption. These stages cannot be separated, as all developing teeth require specific intraosseous constituents for post-eruption reinforcement (Gorski and Marks, 1992; Jain & Rathee, 2022).

2.9.8 Classification of mammalian dentition/teeth

Dentition in different animals are classified according to the replacement or succession of teeth, attachment of teeth to the jaw bones, and structural differentiation of the teeth making up the dentition.

2.9.8.1 Classification based on the tooth size and shape

A. Homodont dentition

Homodont (Isodont) dentition refers to a situation where the shapes and sizes of all the teeth are identical e.g., in fishes, amphibians, reptiles and extinct toothed avian species (Tanika, 2017).

B. Heterodont dentition

Heterodont dentition is characteristic of mammalian dentition. The teeth are classified based on their individual shapes, sizes and functions. The functions also differ at different segments of the rows of teeth. This type of dentition is also present in mammal-like reptiles (Tanika, 2017).

2.9.8.2 Classification based on the means of tooth attachment to the jaw bone

A. Thecodont dentition

In this type of dentition, the teeth are wedged in the alveoli of jaw bones so that blood vessels and nerves go into the pulp cavity via the open apices of the teeth roots. This type of dentition occurs in mammals, crocodiles and in some fishes (Barracuda and Haddock) (Tanika, 2017).

B. Pleurodont dentition

Teeth in this dentition have an attachment with the internal surface of the jaw bones. Some reptiles (Iguana and many snakes) exhibit this type of dentition (Tanika, 2017).

C. Acrodont dentition

In this dentition type, teeth are fixed to the border of the jaw bone by membranous fibrous structure. It is present in amphibians and fishes. Reptiles generally lack the acrodont type of dentition with the exception of some reptiles including Agama lizard and some snakes (Tanika, 2017).

In pleurodont and acrodont dentitions, teeth roots are absent, thus blood vessels and nerves do not go into the pulp cavities at the base.

2.9.8.3 Classification based on the succession or replacement of tooth

A. Monophyodont dentition

Certain mammals develop just one set of dentitions throughout their lives, a situation referred to as Monophyodont, e.g., Marsupials, which only replace their last premolars, the toothed whales (Odontoceti), certain rodents (e.g., squirrels), and some insect-eating animals (e.g., moles). Monophyodont dentition is also present in toothless whales. These whales may not experience any emergence of teeth, while those that experience tooth eruption usually lose them, within a short period of time (Tanika, 2017).

B. Diphyodont dentition

Most mammalian species possess two groups of teeth. The first group is referred to as temporary, deciduous, primary, or milk teeth. They undergo exfoliation and are eventually substituted by a second group of teeth, which are called permanent or permanent teeth. In bats and guinea-pigs, the deciduous teeth are lost before birth. Deciduous dentition is characterised by the absence of molar teeth (Tanika, 2017).

C. Polyphyodont dentitions

This class of dentition is characterised by a constant teeth replacement all through the life of the animal. Many lower vertebrates, including dogfish, snakes, belong to this category (Tanika, 2017).

2.9.8.4 Classification based on trophic specialisation of the cheek teeth (premolars and molars)

A. Bunodont dentition

Present in humans and other omnivorous mammals. It is characterised by the presence of round and distinct cusps in the cheek teeth. These teeth are used for crushing food substances (Tanika, 2017; Meghna, 2023).

B. Lophodont dentition

In this type of dentition, the cusps are united, forming ridges. It is characterised by a complex in-folding of the dentine and enamel and found in the cheek teeth of elephants they are utilized in grinding various plants and grasses (Tanika, 2017; Meghna, 2023).

C. Secodont dentition

Secondont dentition refers to cheek teeth that have razor-sharp shearing crowns. These teeth types are found in carnivorous animals and are utilised in shearing flesh and muscles (Tanika, 2017; Meghna, 2023).

D. Selenodont dentition

Cheek teeth have cusps that appear star-shaped. This type of cheek teeth is present in equines and ruminants, where they are utilised for grinding plants and grasses (Tanika, 2017; Meghna, 2023).

E. Brachydont dentition

A brachydont tooth is made up of a crown, a constricted neck, and a root. In brachydont teeth, the enamel covers the crown while the cementum covers the root. They do not erupt throughout life; they are present in humans, carnivores (dogs and cats), and pigs (Tanika, 2017).

F. Hypsodont dentition

Hypsodont tooth consists of a body and a root; the enamel covers the entire body, but not the root. Hypsodont teeth, made up of all the permanent teeth of horses, cheek teeth of ruminants, and canine teeth of boars, grow throughout their lifetime (Tanika, 2017).

2.9.8.5 Types of Teeth

Heterodont dentition can be classified into 4 types, based on their morphology

a) **Incisors teeth:** They are located on the rostral portion of the mandibles and premaxillae. They are shovel-shaped, with single root and cusp, and are used for cutting and biting food. They are completely missing in sloths, while being absent on the maxillae in ruminants. They have a chisel-shaped in rodents and lagomorphs, where they are open-rooted and have a continuous growth through life (Tanika, 2017; Meghna, 2023).

b) **Canine teeth:** They are positioned singly, on each half of the jaw, caudal to the incisor teeth. They are pointed, with elongated crowns and have only one root. They are used for penetrating and ripping or shearing off the flesh of the prey (dog). They are also useful in clutching preys, as exhibited by carnivores. The canine tooth is absent in rodents and lagomorphs, and the space between the premolar and the incisor teeth is referred to as a diastema. In the equine species, the canine teeth are comparatively small, while in carnivorous species, they appear as spear-shaped structures and are used for penetrating and ripping off flesh (Tanika, 2017; Meghna, 2023).

c) **Premolar teeth:** they are positioned between the canine and molar teeth. They are bicuspid with two or one root and are useful in crushing food during chewing (Tanika, 2017; Meghna, 2023).

d) **Molar teeth:** They are positioned posterior to the premolar teeth and are regarded as the most complicated teeth type. They are, however, absent in temporary dentition. They are utilised in crushing and masticating food particles, and have several cusps with two or more roots. The premolars and molars are collectively called cheek teeth. In carnivorous animals, the cheek teeth number is usually decreased and, in some cases, the last maxillary premolar and first mandibular molar teeth are adapted into pointed cusps, called carnassial teeth, which are used to crack bones and tear muscles (Tanika, 2017; Meghna, 2023).

2.9.9 Tooth replacement in mammals

Mammals generally have a reduced capability for tooth regeneration (Jernvall and Thesleff, 2012). They have two sets of teeth and tooth replacement happens only on one occasion; a phenomenon called diphyodont. The initial series of teeth is called deciduous, primary or milk teeth while the series of teeth that comes after are referred to as adult, permanent, successional or secondary teeth. The incisor, canine and premolar teeth are substituted, but the molar teeth do not undergo any replacement, giving rise to a complex and contentious categorisation of the molar teeth. Molar teeth are occasionally thought to fit in to the initial group of teeth as un-substituted components, since the milk deciduous premolar teeth have striking resemblance with the molar teeth. Molar teeth may have also been grouped as the succeeding group of teeth since they don't have successors, in modern-day mammals. It has however been proposed that they should be considered as a separate group because they have no precursors or replacements (Järvinen, 2008).

2.9.9.1 Diphyodonty in mammals

The fact that tooth substitution has reduced from condition of polyphyodonty in non-mammal vertebrates to vertebrates with diphyodont teeth could be as a result of certain features associated with mammals including a reduction in the sizes of their jaws, increased growth rate to adulthood, the ability to generate and regulate body temperature (endothermy), an efficient integumentary system, ability to nurse their offspring, oro-pharyngeal modifications and efficient masticatory and jaw occluding properties (Järvinen, 2008).

2.10 FACTORS AFFECTING DENTAL DEVELOPMENT AND ERUPTION

2.10.1 Nutritional Imbalances

Nutrients needed for normal development of the teeth include vitamin (vit.) A, vit. C, vit. D, phosphorus and calcium. Phosphorus and Calcium make up the crystals of hydroxyapatite, and the haemo-concentration is sustained by vit. D. Vitamin A is needed for keratin production while vit. C is important in the formation of collagen. Deficiency of calcium, phosphorus, and vit. D results in less mineralization of the hard structures of the teeth while avitaminosis A results in reduced formation of the enamel. Excessive fluoride intake is reported to impede exfoliation and tooth emergence due to its depressing effect on thyroid hormones (Diana, 2015). Severe undernutrition in children has been reported to delay deciduous dental eruption (Kodali, 1998).

2.10.2 Hormonal Imbalances

Growth hormone and insulin-like growth factors have been identified as important factors involved in enamel mineralisation, therefore, in cases of hypopituitarism, odontogenesis is believed to be impaired (Young, 2003). Hyperparathyroidism impedes odontogenesis by obstructing the differentiation of odontoblast precursors to odontoblasts, leading to an unsuccessful odontogenesis (Sakakura, 1987).

2.10.3 Sex

In humans, girls have been reported to erupt their teeth earlier than boys (Demirjian & Levesque, 1980). Significant differences were also reported for maxillary third incisors and canines, and mandibular canine, with an average of 4 to 6 months difference in eruption times. The greatest difference was noted in the permanent canine teeth (Almonaitiene, Balciuniene & Tutkuviene, 2010). Early dental eruption in females can influence the early attainment of sexual maturity (Tucker & Widowski, 2009).

2.10.4 Physical disturbances

Physical disturbances like trauma and excessive heat may lead to altered epithelial and mesenchymal interactions during odontogenesis, which ultimately results in a developmental anomaly of the affected teeth. Anomalous size, number, structure, and or shape of teeth can ensue and this is contingent on the stage of development at which the abnormalities occur (Shrestha, Marla, Shrestha, & Maharjan, 2015).

2.10.5 Environmental chemicals and drugs

Common environmental chemicals, drugs, or physical agents have severe effects on the embryonic development of the human teeth, as well as after their eruption into the mouth. Lead has been implicated as a common toxic metal and teeth are reported to accrue lead during development. Human and animal researches have revealed that accumulation of lead have made affected teeth more prone to the onset and development of dental caries. Teratogenic agents, such as tetracyclines generally result in the discolouration of tooth enamel of infants and children, when used during pregnancy. Exposing children to cigarette fumes may also increase the possibility of the development of various lesions on the teeth, just as it has been associated with adult periodontal disease (Billings, Berkowitz & Watson, 2004).

2.11 DENTITION IN PIGS

All pigs, including the Nigerian indigenous pig, are diphyodonts with heterodont dentition; they have two sets of dentitions (temporary and permanent dentition) consisting of four different types of teeth (incisor, canine, premolar and molar) (Smith *et al*., 2020).

Calcification of deciduous teeth starts in utero and piglets are born with eight teeth called “needle teeth”. These teeth are

i. Deciduous or temporary and include the third incisors and the canines of the mandible and maxilla.
ii. Sharp and project laterally from the gums. Hence, they are usually snipped, post-partum to avert injuries to the nipples of the sow.
iii. Important in forming "teat order", a form of competition amongst piglets for the most productive mammary gland of the sow (Tucker and Widowski, 2009).

As piglets grow, they erupt other temporary teeth (first and second incisors and four premolars) after which they are replaced by permanent teeth. These teeth are brachydonts except the canines, which, in boars, grow throughout their lives. Pigs, just like humans, have simple (haplodont) incisors with pointed crowns and trabeculate (bunodont) cheek teeth with wide crowns (Tanika, 2017).

2.11.1 Description of teeth in pigs

2.11.1.1 Incisor teeth

The maxillary incisors are small and a sizeable gap separates them from the canine teeth. The first incisor teeth are large, flat and curved, with convergent crowns, no definite neck region (Fig. 2.9). The labial surface is convex, with a widespread coverage by the enamel while just a little region of the lingual surface has an enamel covering. The second incisor teeth are shorter than the first and somewhat curled, with short flat crowns and round roots. The third incisor (corner) teeth are significantly smaller and laterally flattened (Belu *et al*., 2021; Allred, 2022).

The mandibular incisor teeth appear nearly straight and compacted. The first two incisor teeth are rod-like, somewhat curled and firmly rooted in the jaw, having nearly the same size (Fig. 2.10). The labia-facing side shows some measure of convexity while the opposite side (lingual) shows some measure of concavity and marked near its edge by a crest. The third incisors are similar to their maxillary counterparts, with narrow crowns and obvious necks (Belu *et al*., 2021; Allred, 2022).

2.11.1.2 Canine teeth

They are well developed in adult pigs and project out of the mouth, being more developed in males. It is modified into the tusk in wild boars and are thus regarded as weapons of offence and defense. In both sexes, their growth is permanent. The length of the maxillary canine in the boar ranges between 3-4 inches/8-10 cm, not exceeding 12cm in mature boars. The canine tooth has a cone-shaped crown, giving it a thick base appearance. It has an outward and backward-pointing curve-like appearance. The part of the tooth located with the alveolar bone is also greatly curved, with a big pulp cavity (Belu *et al*., 2021; Allred, 2022).

The mandibular canines can grow to 8 inches and above (20cm), in mature boars. The crown has the shape of a prism and curves outward and backward, being positioned rostral to the maxillary counterpart (Belu *et al*., 2021). Frictional forces between both canine teeth ensure that the mandibular canine tooth possesses a sharpened tip. The porcine canine teeth are "rootless" and are capable of growing continuously (aradicular, hypsodont, and elodont) (Smith *et al*., 2020).

2.11.1.3 Premolar and molar teeth

The porcine cheek teeth enlarge in dimension cranio-caudally. They are brachydonts with bunodont crowns, compared to the lophodont and selenodont teeth found in the equine and bovine species, which have obvious enamel ridges on the crown. The first premolar possesses 2 roots and remaining three premolars have 3 to 4 roots. The molar teeth possess 4 roots but the rostral pair is usually joined (Belu *et al*., 2021; Allred, 2022).

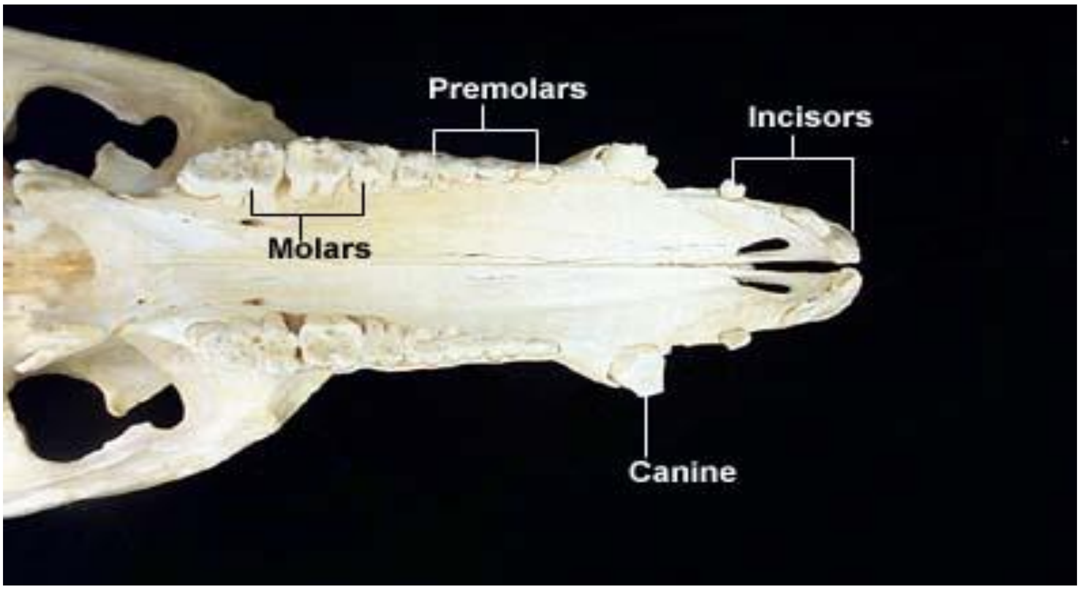

Figure 2.19: Maxilla of an adult boar showing complete dentition (Rouge, 2022).

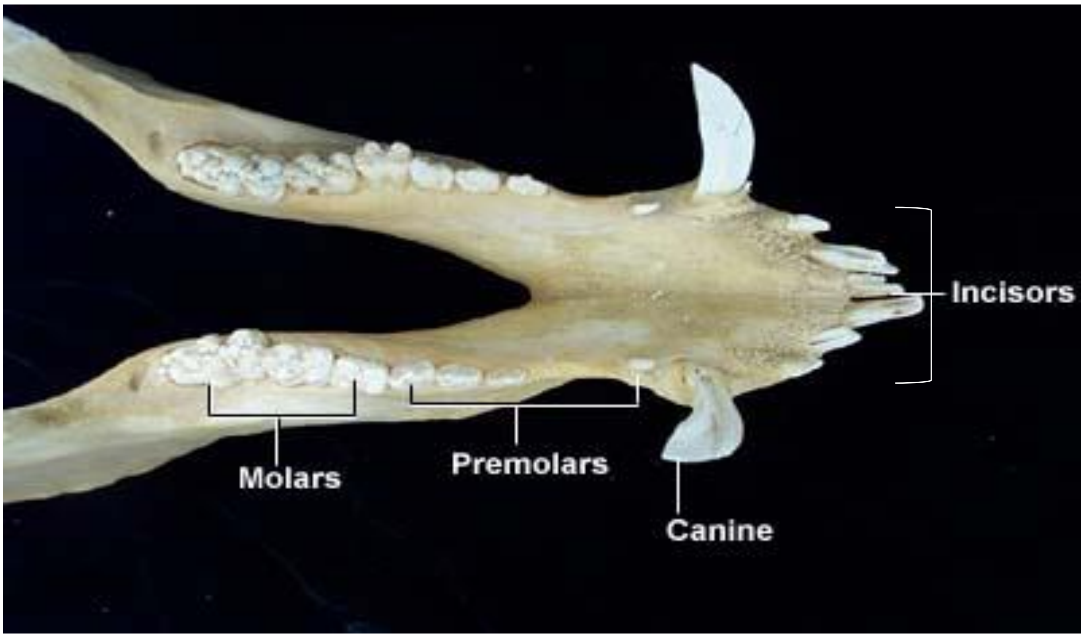

Figure 2.10 Mandible of an adult boar showing complete dentition (Rouge, 2022).

2.11.2 Dental formula and eruption time in domestic pigs

The number of each type of tooth, on each side of the jaw, is referred to as the dental formula. In a dental formula, the maxillary and mandibular teeth on the quadrant of each jaw are shown on single lines. Since 4 quadrants exist in the mouth, the number of teeth in the oral cavity is usually double of what is written out. The incisors (I) are written first, followed by the canine teeth (C); then the premolar teeth (P), and lastly, the molar teeth (M) (Mai, Young & Kersting, 2005). For the temporary dentition, lower case letters are used and these letters are preceded by "d" to indicate their deciduousness. Block letters are used to indicate the different teeth making up the permanent dentition.

In pigs, temporary or deciduous dentition consists of 28 teeth (2 × di; dc; dp) (St Clair, 1975; Tonge & McCance, 1973; Wang *et al.,* 2007; Swindle, 2010) while permanent or permanent dentition consists of 44 teeth (2 × I; C; P; M) (St Clair, 1975; Tonge & McCance, 1973).

NOTE: 2 × di indicates that there are three pairs of deciduous incisors on each quadrant of the mandible and the maxilla. Some researchers record the deciduous premolars as deciduous molars, that is, "dm" instead of "dp" (St Clair, 1975; Weaver *et al*., 1966; Swindle. 2010).

Table 2.2. Overview of teeth eruption time in domestic pigs

Teeth	Temporary	Permanent
Incisor 1	2–4 weeks	12 months
Incisor 2	Maxillary 2–3 months	12 months
	Mandibular 1½–2 months	16–20 months
Incisor 3	Before birth	8–10 months
Canine	Before birth	9–10 months
Premolar 1	5 months	
Premolar 2	5–7 weeks	
Premolar 3	Maxillary 4–8 days	
	Mandibular 2–4 weeks	12–15 months
Molar 1		4 – 6 months
Molar 2		8 – 12 months
Molar 3		18 – 20 months

(St Clair, 1975)

2.11.3 Methods of ageing wild pigs

Feral and wild pigs (*Sus scrofa*) have been reportedly aged by

1. Teeth eruption and replacement patterns
2. Lines of cementum
3. Width of incisor pulpar cavity
4. Weight of the lens of the eye
5. Fusion of the epiphyseal plate
6. Morphometrics (Choquenot & Saunders, 1993).

2.11.4 Factors affecting dental eruption in pigs

Factors that have reported to affect the emergence of teeth in porcine species include:

1. Physical disturbance (Wise *et al.,* 2002).
2. Abnormal bone development (Wise *et al.,* 2002).
3. Hormone insufficiencies, along with many genetic syndromes (Wise *et al.,* 2002).
4. Systemic stress which is nutritional in nature (Tonge & McCance, 1973).

2.12 DENTAL ANOMALIES

Dental anomalies can be described as obvious variations from typical dental architecture (Karjodkar *et al*.,2012; Shrestha *et al*., 2015). They occur in the course of the evolution and formation the components of the dental tissue, including the enamel, dentine or cementum (Penzhorn, 1984). These anomalies or disorders can be divided into two groups: developmental and acquired anomalies (Shokri, Mortazavi, Baharvand, & Movahhedian, 2015). It is important to know the typical structural and functional dental characteristics for individual animal species, as this knowledge will facilitate the comprehension of the onset and development of some dental anomalies, including persistent deciduous teeth, dental attrition, tooth fracture, and periodontal diseases (Sauer, Oliveira, Andrade, da Silva, de Lavor, Wenceslau & Carlos, 2018).

2.12.1 Developmental dental anomalies

Developmental anomalies may be genetically induced by abnormalities in the differentiation and formation of the dental laminae, dental buds and dental tissues, or may be environmentally induced by trauma, chemical, and microbial irritations (Pavlica *et al*., 2001; Okandeji *et al*., 2023a). Based on the stage of dental development wherein an alteration takes place, various deviations could reflect in contour, colour, structure, size, number, shape and degree of teeth development (Karjodkar *et al.,* 2012; Shrestha *et al*., 2015). Developmental anomalies can therefore be categorised into 5 groups viz: abnormalities in structure, size, morphology, number, and position of teeth (Shokri *et al*., 2015; Okandeji *et al.*, 2023a).

2.12.1.1 Number of teeth

a. Hypodontia**:** This is a developmental absence or reduced number of teeth. In humans, this condition is uncommon in deciduous dentition, with a prevalence of 0.5-0.9% and lateral incisors are usually involved. Hypodontia is associated with microdontia (Shokri *et al.,* 2015). Oligodontia and anodontia are used to depict more severe types of hypodontia, and are characterised by the non-existence of more than six teeth and the entire dentition, respectively (Guttal *et al*., 2010; Al-Ani, Antoun, Thomson, Merriman, & Farella, 2017).

b. Hyperdontia (Supernumerary teeth): This is development of excessive number of teeth. It is less common in deciduous dentition, with a prevalence of 0.3-0.8% in man. It is associated with macrodontia and is seen more commonly in males than females. Supernumerary teeth are mostly observed on the jaw bones but they have also been reported to be present on the gum, nasal cavity, maxillary sinus, facial tuberosity, and the soft palate (Shokri *et al.,* 2015).

2.12.1.2 Shape of teeth

Over 300 genetic materials have been identified to be involved in the development of a tooth. Errors in these genetic materials are reported to be one of the factors responsible for the change in the shape of a tooth (Shrestha *et al*., 2015).

a. Gemination: This condition is also called double or fused teeth and usually affects the rostral maxillary teeth. It is described as the development of similar teeth from a single dental follicle, with indications of an effort by the affected teeth to be separated from one another. The failure of a complete division of the tooth into 2 separate teeth results in the tooth having two individual crowns or a sizeable, partially separated tooth crown with one tooth root and canal (Shrestha *et al.*, 2015; Rathee & Jain, 2021).

b. Fusion: Describes the situation where the enamel and dentine of 2 or more adjacent developing teeth unite. It is thought to arise due to the close apposition of developing teeth during the eruption or pre-calcification stage, caused by the effects of natural forces produced during the development. Infections caused by viruses, and thalidomide ingestion, by pregnant mothers, have also been suggested as possible aetiologies of the condition (Shokri *et al*., 2015; Shrestha *et al*., 2015). Fusion may affect deciduous and permanent dentition; its occurrence is however higher in deciduous dentition. It often results in a reduction in the number of teeth. Fusion of adjacent teeth may lead to the formation of an abnormal tooth size, due to a full merger. It may also result only in the merger crowns or roots and may sometimes be accompanied with missing succeeding teeth (Shokri *et al*., 2015; Shrestha *et al*., 2015).

Contingent on the developmental phase, fusion can either be complete (full/whole/absolute) or incomplete (half/partial/imperfect). If fusion commences prior to the teeth being calcified, there is a complete joining and incorporation different parts of the affected teeth. Incompletely fused teeth are observed at later stages and the ensuing tooth might display distinct crowns and roots with merged or distinct pulp cavities (Shrestha *et al*., 2015; Rathee & Jain, 2021). Fusion may result in a tooth being missing, either in the deciduous or permanent dentition (Shokri *et al*., 2015; Shrestha *et al*., 2015).

c. Concrescence: Is the root attachment of two or more neighbouring teeth to one another via the cementum. It can affect deciduous and permanent dentition. Even though its aetiology is not known, the condition is thought to arise due to several factors including insufficient distance between adjacent teeth during development, traumatic injuries, and atypical occlusal forces (Shokri *et al*., 2015; Shrestha *et al*., 2015; Rathee & Jain, 2021). Concrescence can happen in the course of root formation (developmental or true concrescence) or when it is completed (post-inflammatory or acquired concrescence) (Shokri *et al*., 2015; Shrestha *et al*., 2015).

d. *Dens evaginatus*: It is an uncommon tooth abnormality, seen on the occluding surface. It is characterised by the presence of a circumscribed part of the crown that projects outwardly, resulting in a projection on the affected area that looks like an additional or extra cusp (Guttal *et al*., 2010; Shokri *et al*., 2015). Although commonly observed on the premolar teeth, it can be present on other tooth types, with the mandible being more commonly affected. It arises from an aberrant growth of the inner surface of the epithelium of the enamel into stellate reticulum (Shokri *et al*., 2015). This rare abnormality protrudes beyond the surface of the tooth, thus affecting normal occlusion of affected teeth.

Talon cusp is a manifestation of *dens evaginatus* in the maxillary teeth. It is characterized by the presence of an extra or additional tooth cusp, which bears a resemblance to the talon of an eagle (Karjodkar *et al.,* 2012; Shrestha *et al*., 2015). It is usually located on the lingual surfaces, and seldomly on the labial surfaces of deciduous or permanent incisor teeth. In both types of dentitions, it arises at the junction between the cementum and the enamel of rostral mandibular and maxillary teeth (Guttal *et al*., 2010). Large talon cusps impede normal occlusion of teeth.

e. *Dens invaginatus*: This abnormality is also called the "dens in dente", extensive compound odontoma or "pregnant woman anomaly". It occurs because of an invagination on the outer side of the crown of the tooth prior to it being calcified (Karjodkar *et al.,* 2012; Thakur, Thakur, Bramta & Gupta, 2014; Shrestha *et al*., 2015). The invagination extends from a short pit in the crown to a profound root invagination and may extend to or past the tip of the root (Shrestha *et al*., 2015; Shokri, 2015).

f. Dilaceration: is a developmental disorder which connotes an alteration in the association between the crown and root of a developing tooth, resulting in an intense curvature of both parts of the tooth (Karjodkar *et al.,* 2012; Shrestha *et al*., 2015). This condition happens due to traumatic injuries, in the course of the development of the tooth, which leads to an alteration, secondary to trauma during the tooth formation, altering the positional slant between the root and developed crown of the tooth. The curve may also arise as a result of pressures from nearby structures. Occasionally, the bend is created due to the pressure from the adjacent growths, cancers or odontogenic hamartomas (Karjodkar *et al.,* 2012; Shrestha *et al*., 2015). Root dilacerations occur more frequently when compared to occurrences in the crown (Shrestha *et al*., 2015), while permanent teeth are more susceptible to dilacerations, when compared to the deciduous teeth (Rathee & Jain, 2021).

2.12.1.3 Size anomalies

a. Microdontia: Is characterised by smaller-than-normal teeth. Relative microdontia is observed when the jaws are bigger than usual, making the teeth appear smaller than normal in size. Absolute widespread microdontia is not common (Shokri *et al.,* 2015). The condition is more common in the permanent maxillary lateral incisor teeth (Carlson, 2014).

b. Macrodontia: Also referred to as megadontia/megalodontia. In this case, teeth are actually larger than normal and has nothing to do with normal-sized teeth being present on small jaws (Shokri *et al.,* 2015; Chetty, Beshtawi, Roomaney, & Kabbashi, 2021). The condition is reportedly associated with several endocrine and genetic anomalies and may be classified as true generalized macrodontia, relative generalized macrodontia or macrodontia of a single tooth (Chetty *et al*., 2021).

2.12.1.4 Structural abnormalities

a. *Amelogenesis imperfecta*: This is hereditary alterations in the structure and appearance of dental enamel before or after tooth eruption. It impacts the morphological and medical manifestations of several teeth in the affected individual. It can be hypoplastic, hypocalcified, or a combination of the two, in nature. Patients have discoloured hypersensitive teeth, which are prone to breakage. In humans, the anomaly can appear as sporadic, autosomal recessive, X-linked or autosomal dominant in its pattern of inheritance (Gadhia, McDonald, Arkutu, & Malik, 2012; Shokri *et al.,* 2015).

b. *Dentinogenesis imperfecta*: It is a basic developmental anomaly in the dentine, which may also result in the formation of thin enamel layer. It has been reported in deciduous and permanent teeth. Affected teeth may appear as grey blue, or amber brown and opalescent, with reduced height. Hereditary pattern is that of an autosomal dominant type. Three forms of this condition have been reported viz: types I, II and III, based on their association with *osteogenesis imperfecta* (Shokri *et al.,* 2015; de La Dure-Molla, Philippe Fournier, & Berdal, 2015).

2.12.1.5 Positional abnormalities

a. Transposition: Is characterised by the displacement of teeth because they are not properly positioned on the dental arch. In man, it is frequent in the canine and first premolar teeth, followed by the lateral/third incisor teeth. Its occurrence is uncommon in deciduous dentition. This condition may be linked to hypodontia, persistent deciduous teeth and supernumerary teeth (Shokri *et al.,* 2015).

2.12.2 Acquired abnormalities

a. Tooth discolouration is an alteration in the typical colour (hue, chroma, value or translucency) of a tooth. It is categorised, based on the position of the colour, as intrinsic, extrinsic or internalized stains/ discolouration. In certain instances, stains are regarded as an indication of a general body disorder (Watts & Addy, 2004; Mahmoodian & Hashemi, 2004; Mortazavi, Baharvand M & Khodadoustan, 2014).

The typical temporary teeth are lighter in colour, usually appearing as white. They become darker as such individuals grow older and possess permanent dentition (Watts & Addy, 2004; Mahmoodian & Hashemi, 2004) and this might occur as a consequence of the deposition of secondary dentine, absorption of extrinsic dyes and the steady enamel wear, resulting in an increased expression of the colour of the dentine that lies. Dental wear and recession of the gum have also been implicated in tooth discolouration (Watts & Addy, 2001; Mortazavi *et al.*, 2014).

b. Ankylosis: It is an anomalous condition wherein a connection between alveolar bone and cementum or dentine occurs pre- or post-eruption. It also refers to cessation of eruption after teeth emergence (Shokri *et al.*, 2015). The aetiology is unknown; but, several factors including genetic alterations, traumatic injuries to bone or periodontal ligament, local defective bone growth, metabolic disorders and focal inflammatory responses have been implicated (Shokri *et al.*, 2015).

c. Resorption: This is the damage of tooth configuration owing to the activities of osteoclasts. Two types of resorption have been identified, based on the altered areas on the tooth; external and internal resorption (Shokri *et al.*, 2015).

d. Attrition: Dental attrition or wear, is caused by interaction between teeth or crushing actions of opposite teeth (bruxism), during masticatory or occlusal activities, resulting in the development of attrition surfaces on the primary surface of enamel (Shokri *et al*., 2015: Sperber, 2017). Tooth wear, past a particular position, results in a reduction in the operational effectiveness of such tooth. This is usually associated with a total or incomplete enamel loss from the contact surface (Ungar, 2015).

e. Erosion: Is described as the damage to the structure of the teeth as a result of the effects of chemical substances, which are not produced by bacteria. In man, signs of erosion are observed on the palatal and labial surfaces of the rostral maxillary teeth, and occlusal and lateral gingival surfaces of the caudal mandibular teeth. Classical evidence of this condition is a concave dentine bounded by pointed enamel edges. Areas of active erosion are clear and uncontaminated while the inert areas have signs of staining (Shokri *et al*., 2015)**.**

f. Abrasion: This is a form of tooth wear that occurs as a result of mechanistic trauma. The appearance is different depending on the cause of abrasion (Shokri *et al*., 2015)**.** It is caused by contact between the teeth and food substances or foreign bodies which can destroy or alter the pattern of wear (Sperber. 2017).

g. Dental caries: This condition may be described as a discoloured and demineralised region on a tooth surface which affects the enamel, dentine, and could eventually involve the pulp and other structures around the tooth. This demineralisation arises from the activities of organic acid-producing microorganisms in dental plaques, via the anaerobic breakdown of carbohydrates present in diets (Moynihan & Petersen, 2004; Malmsten *et al.,* 2015; Okandeji *et al*., 2023a). A persistent demineralisation precedes the development of a dental hollow, leading to microbial contamination of the pulp and consequently, serious discomfort (Malmsten *et al.,* 2015). Although diet has been implicated in the onset of carious lesion, other factors that may impact an animal's predisposition to the condition include the tooth susceptibility, nature of bacteria, the salivary quantity and quality, and the duration of cariogenic bacterial action on the carbohydrates in the diet (Moynihan & Petersen, 2004; Malmsten *et al.,* 2015).

2.13 BONE PREPARATION

Preparation of the skeleton of an animal's carcass includes the removal of soft tissue, disarticulation, cleaning, degreasing, and labelling of bones. The time it takes for this processes to be completed largely depends on the size of the animal (Boyle, 2010).

The process of preparing skeletons or bones from carcasses is a common practice in many fields where these skeletons are required for research and comparative studies, display or collection, (Leeper, 2015). The process of removal of soft tissues from bones is called defleshing, skeletal processing or skeletal preparation. It is reportedly common, with an extensive history, and the methods employed in defleshing vary, based on fields of use and the desired outcomes (Leeper, 2015).

2.13.1 Bone maceration

Maceration, which describes the process of soft tissue removal from bones soaked inside water, by the action of bacteria, for further examination (Couse & Connor, 2015; Leeper, 2015). It has been used synonymously to describe the process of defleshing bones by the use of chemicals and enzymatic reactions (Leeper, 2015). Maceration processes play vital roles in the field of anthropology and forensic pathology (Uhre *et al*., 2015), and is achieved by a breakdown of biomolecules, especially structural proteins (Offele, Harbeck, Dobberstein, Wurmb-Schwark & Ritz-Timme, 2007).

Several "defleshing" techniques have been reported but they can be categorised into 6 groups:

1. Bacterial maceration using cold water.
2. Hot water maceration (boiling/ cooking).
3. Chemical maceration using various chemicals like household bleach or sodium perborate.
4. Enzymatic maceration, using proteolytic enzymes such as papain, trypsin, or an enzyme-active laundry detergent.
5. Invertebrate maceration, using carnivorous invertebrates such as dermestid beetles.
6. Burial of carcass and subsequent exhumation, after an extended period of time, to allow for natural bacterial decay. (Steadman, DiAntonio, Wilson, Sheridan, & Tammariello, 2006; Leeper, 2015).

It has been reported that all the methods used to remove soft tissues resulted in morphological changes and removal of dental caries/plaques, as well as colour of teeth (Offele *et al*., 2007).

CHAPTER THREE

MATERIALS AND METHODS

3.1. STUDY ONE

3.1.1 Deciduous dental eruption pattern in the Nigerian indigenous pig

3.1.2 Study animals

Six Nigerian indigenous pig sows and one boar, with a history of extensive husbandry, were purchased from Gbogan and Iseyin, in Ibarapa North and Iseyin Local Governments, Oyo state, respectively. Their ages were estimated to be between 18 months and 2 years, according to St. Clair (1975). They were transported from their local environments and accommodated in pens made of concrete, at the University of Ibadan Teaching and Research farm. A blend of concentrate (calcium-2.45%, crude protein-16.06%, and metabolisable energy-2,695 kcal/kg), brewery wastes, palm kernel cake (PKC) and fermented cassava peels was sufficiently provided, as their source of nutrition. Water was also provided, *ad libitum.* They were allowed to acclimatize for about two months before mating took place. The period of acclimatization was for them to get used to being handled under intensive husbandry practice. Natural mating took place between the boar and the sows. Fifty-one (51) fit piglets (new born) farrowed from the mating process were used for this study.

3.1.3 Methods: Deciduous dental eruption

After farrowing, the piglets were gently but properly restrained and their oral cavities were opened and examined for the presence of needle teeth, using sterile wooden spatulas, under natural light. Piglets have been reported to be born with 8 needle teeth (Tucker & Widowski, 2009). Thereafter, the oral cavities of the piglets were examined three times a week, from postnatal day one till the emergence of the last deciduous tooth, which occurred between four and five months of age. To achieve this, the piglets, after proper restraints, were positioned dorsally or laterally, and their oral cavities were gently opened to allow for the careful inspection of all the corners of the dental arches (left and right mandibular, left and right maxillary). A research assistant recorded the findings. Tooth eruption was deemed to have taken place when any part of the crown of the tooth appears above the gum, after its penetration through the gum (Suri *et al*., 2004; Tucker & Widowski, 2009).

3.2 STUDY TWO

3.2.1 Permanent dental eruption pattern of the Nigerian indigenous pig

3.2.2 Study animals

From the 51 piglets, twenty-six (26) of them developed into healthy adult pigs (12 males and 14 females) which were used for this study. They were therefore accurately aged from birth records (oral examination started at 6 months of age). Accommodation and feeding was as described in study.

3.2.3 Methods: Permanent dental eruptions

The pigs used for this study were handled humanely by qualified personnel to rule out any form of pain and discomfort the animals might be subjected to. They were securely held and placed in a lateral or dorsal recumbency and their mouths firmly and gently opened for observation of all corners (left and right mandibular, left and right maxillary). Observation for eruptions was done three times a week, between 16^{th} and 52^{nd} week of life. According to St Clair (1975), this period is characterised by the rapid replacement of deciduous teeth with permanent teeth. Afterwards, observation for dental eruptions was done weekly, until the emergence of the 3^{rd} molar tooth (146 weeks). This period is characterised by a much slower tooth replacement process (St Clair, 1975). A tooth was deemed to have erupted once any portion of the crown was observed to have emerged above the gingiva (Suri *et al.,* 2004; Tucker & Widowski, 2009).

3.2.4 Statistical Analysis

The data obtained from the observations made in studies one and two were subjected to Student's *t*-test using GraphPad Prism 5®. Data obtained were expressed as Means with the standard error of mean (Mean±S.E.). Statistical significance level was set at $\alpha_{0.05}$. The dental eruption sequence was obtained by arranging the average values of the age of eruption of every tooth, for every piglet and adult pig, in an increasing order.

3.3 STUDY THREE

3.3.1 Dental anomalies in the Nigerian indigenous pig

3.3.2 Study animals

For this study, fifty-one pig heads (25 males, 26 females) were obtained, after certifying that they were healthy and had no evidences of skull defects. The pigs had previously been used in experiments one and two, as stated above. They were selected in such a way as to have representative samples in each age group to be used for the study. The animals were selected during and after the dental eruption studies previously described. They were properly restrained and sacrificed by quick decapitation at the occipito-atlantal joint. They were sorted according to individual age (below 6 months, 6-15 months and above 15 months). Individual animals were aged using the birth records obtained from previous studies (3 months to 51 months).

3.3.3 Skull maceration process

Preparation of the severed heads was done by means of a modified hot water maceration technique, as outlined by Onar (1999) and Olopade and Okandeji (2010). This modification was on the basis of heating period to prevent excessive maceration of bone tissues so that the skull bones could remain intact, as much as possible. The technique is briefly described below:

(i) After flaying the skin and removing most of the muscles and other soft tissues, including the brain tissues (with sharp knives scalpel blade on a holder and probe), the heads were placed in large metallic pot of water, containing polycarboxylate and anionic surfactant (detergent) and soap chips, and heated to over 100^{o}c for 45 minutes to 120 minutes.

(ii) The heads were frequently checked; especially those of the piglets, as prolonged cooking can damage the skull or dissolve bone tissues. After boiling, the heads were removed from the boiling water put under running water to remove any remaining muscle, ligaments or soft tissues, by using sharp knives, scalpel blades and a pair of forceps. In most cases, this process was sufficient to rid the skulls of any soft tissue.

(iii) The mandibles were, thereafter, disjointed from cranium (upper skull), to provide a comprehensive assessment of the dental anomalies. The skulls were soaked in water, containing detergent, for about 24 hours, and ligaments and muscles were further removed, if any.

(iv) The skulls were then placed in a solution containing 0.3-0.5% Sodium Hypochlorite (bleach) and hydrogen peroxide for 24 hours to bleach them. Care was taken not to over bleach the skull bones.

(v) Thereafter, the skulls were rinsed under running water for a few minutes, after which the skulls were left in the sunlight to dry for about a week.

3.3.4 Identification of dental anomalies

After sun drying, the skulls were properly marked using permanent markers and a systematic examination of the jaws was done, to identify the dental anomalies present. Detailed examination of the teeth was done by visual assessment of the skulls and subsequent grading of observed anomalies. The severity of the anomalies were graded as – (absent), + (mild), ++ (moderate) or +++ (severe). The assessment was done by an independent examiner, skilled and trained in the identification of developmental and acquired dental defects. All observed anomalies and level of severity were documented, while photographs of the anomalies were obtained using a Nikon COOLPIX L320® digital camera (16.1Megapixels). Percentage prevalence was computed as the proportion of the occurrence of an anomaly in an individual animal skull, as against the overall skulls examined.

3.3.5 Ethical Approval

Ethical Approval for the study was obtained from the University of Ibadan animal Care and Use Research Ethics Committee (UI-ACUREC) (UI-ACUREC/20/009).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Deciduous dental eruption pattern in the Nigerian indigenous pig

The range and average values of the age of deciduous dental eruptions are as shown in Table 4.1 while pictorial evidences of eruption are seen in Plates 4.1- 4.8. All piglets examined in this study were born with eight teeth (needle teeth), made up of a canine and third incisor teeth, in each quadrant of the oral cavity (Plate 4.1).

The mean eruption time was lower in female piglets, when compared to what was observed in male piglets. Results from the study revealed that female piglets had earlier eruptions of 50% (n=5) of all examined teeth, ahead of the males (di_1, dp_3, dp^3 di^1, di_2). Females equally completed eruptions in 60% (n=6) of all teeth examined, ahead of the males (dp_3, dp^3, dp_4, dp^4, di_2, di^2). Only one tooth (di_1) showed evidence of the completion of its eruption process in males, ahead of female piglets. These results were, however, not statistically significant (Table 4.1).

Using the mean time for the dental eruption, the eruption sequence revealed a progression from one tooth to the next (Table 4.1). However, slight variations were observed in some piglets. The variations observed in the eruption of the tooth eruptions affected the incisor and premolar teeth. Findings revealed that 10 piglets (20%) had eruption of the first maxillary incisor tooth earlier than the third maxillary premolar tooth, whereas 22% (n=11) of them showed evidence of erupting the fourth premolar tooth ahead of the second premolar tooth, on the mandible.

Evidence of tooth discolouration (stains) was observed on the needle teeth, in a number of piglets, from each litter. These stains differed, from a deeper shade of yellow to a darker shade of brown colourations (Plates 4.2-4.3).

Extra maxillary third incisor tooth (polydontia) was noticed in two female piglets. This condition was bilateral in the affected piglets. Similarly, a polydontia of the maxillary third incisor was observed in a male piglet but it was unilateral (left). In all concerned piglets, these extra teeth were flanked by the third incisor and canine teeth (Plates 4.4-4.5.

Table 4.1. Mean±Standard error of the age of eruption of maxillary and mandibular deciduous teeth in the Nigerian indigenous pig (piglets)

	MALES (n=24)		FEMALES (n=27)	
Tooth Eruption	**Mean ± S. E**	**Range (Days/wks)**	**Mean ± S. E**	**Range (Days/wks)**
Man. di_1 (days)	12.95±0.73	8–18	12.54±0.74	7–23
Max. di^1 (wks)	3.75±0.15	3–5	3.28±0.22	2–5
Man. di_2 (wks)	11.08±0.40	6–14	10.67±0.39	5–13
Max.di^2 (wks)	17.91±0.58	12–24	16.91±0.53	12–20
Man. dp_2 (wks)	5.73±0.71	3–13	5.59±0.68	3–13
Max. dp^2 (wks)	7.65±0.20	6–9	7.33±0.16	6–9
Man. dp_3 (wks)	3.63±0.23	2–6	3.26±0.22	1–5
Max. dp^3 (wks)	3.38±0.25	2–7	3.19±0.24	1–6
Man. dp_4 (wks)	6.25±0.17	4–8	6.15±0.17	4–7
Max. dp^4 (wks)	6.33±0.17	5–9	6.00±0.19	5–8

Note: Wks (Weeks)

Note: Man: mandibular tooth; Max: maxillary tooth

d: deciduous

i: deciduous incisor

p: deciduous premolar

1: first tooth in the series

2: second tooth in the series

3: third tooth in the series

4: fourth tooth in the series

The sequence of deciduous teeth eruptions was:

di_3 /di^3 (pre-natal), c (pre-natal) $di_1 \rightarrow dp_3 \rightarrow dp^3 \rightarrow di^1 \rightarrow dp_2 \rightarrow dp_4 \rightarrow dp^4 \rightarrow dp^2 \rightarrow di_2 \rightarrow di^2$

Plate 4.1: Photograph of the oral cavity of a four-day old NIP piglet, with arrows showing the mandibular and maxillary third incisor and canine teeth (needle teeth).

Plate 4.2: Photograph of the oral cavity of NIP weaner with black arrow showing erupted mandibular second premolar tooth. Note the presence of stained maxillary canine tooth (yellow arrow) and third incisor tooth (white arrow).

Plate 4.3: Photograph of the oral cavity of NIP grower with Left-Right arrow showing stained third maxillary incisor and canine teeth.

Plate 4.4: Photograph of the oral cavity of NIP grower with white arrow showing polydontia of the left third maxillary incisor tooth. The extra incisor tooth is located between the third maxillary tooth (red arrow) and the maxillary canine tooth (black arrow).

Plate 4.5: Photograph of the oral cavity of NIP grower with white arrow showing polydontia of the right third maxillary incisor tooth. The extra incisor tooth is located between the third maxillary incisor tooth (red arrow) and the maxillary canine tooth (black arrow).

Plate 4.6: Photograph of the oral cavity of NIP piglet with arrow showing bilaterally erupted maxillary third premolar teeth.

Plate 4.7: Photograph of the oral cavity of NIP piglet, with arrow showing the eruption of the fourth maxillary premolar tooth directly behind an erupted third premolar tooth.

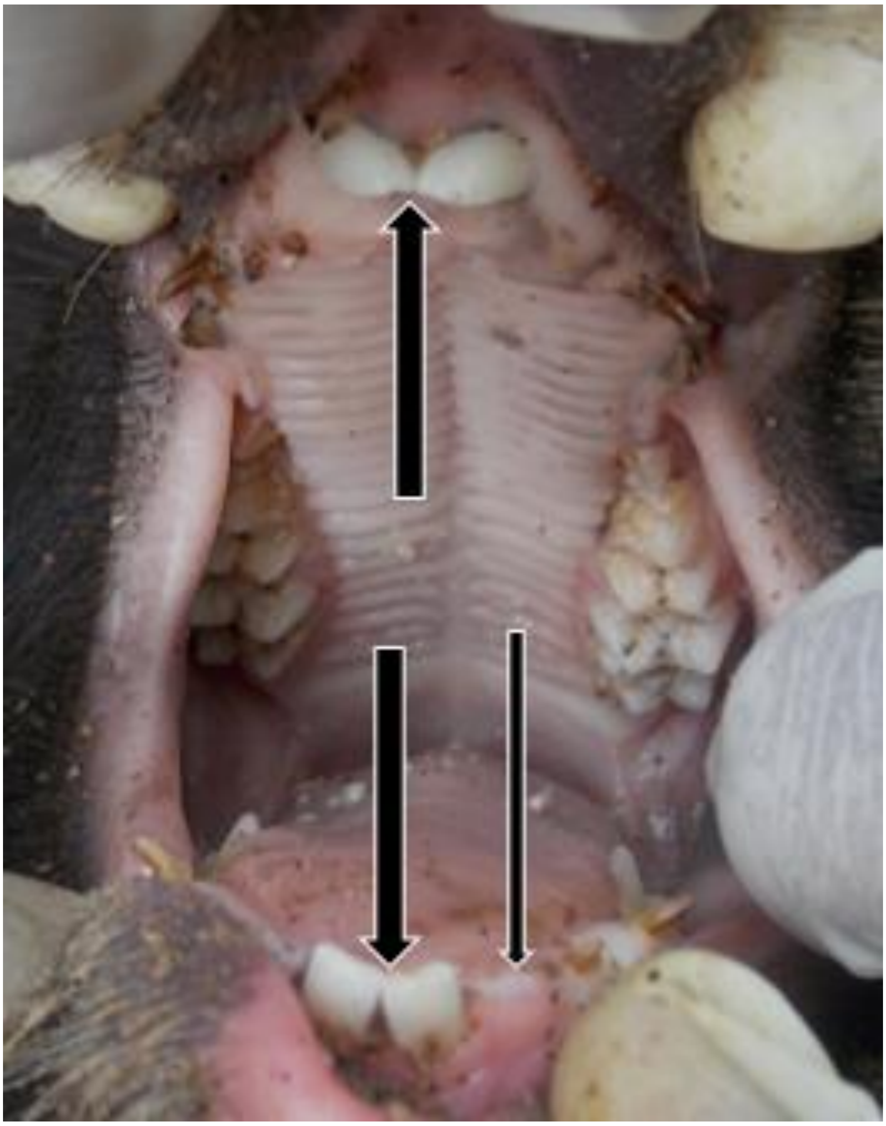

Plate 4.8: Photograph of the oral cavity of NIP grower, with thick arrows showing the central incisors (mandibular and maxillary first incisor teeth), and second mandibular incisor tooth (thin arrow).

4.1.2 Permanent dental eruption pattern in the Nigerian indigenous pig

The range and average values of the age of permanent dental eruptions are as shown in Table 4.2. The result obtained from the study showed that male NIPs had lower mean values for age of eruption in 54.5% (n=12) of all examined teeth (I^3, C^1, C_1, P_1, P_2, P^2, P_3, P^3, P_4, M^2, M_3, M^3), when compared to the 13.6% (n=3) that was observed in the females. However, in both sexes, 31.8% (n=7) of the teeth eruption occurred almost around the same time. Eruption was completed in 59.1% (n=13) of the examined teeth in the males (I_1, I^1, I^3, C^1, P_1, P_2, P^2, P_3, P_4, M_2, M^2, M_3, M^3), ahead of the female NIPs. The mean values for the age of eruption were significantly lower in the males, for the maxillary and mandibular canines ($P<0.01$ and $P<0.001$, respectively), the third maxillary incisor tooth ($P<0.01$), and the fourth mandibular premolar tooth ($P<0.05$), when compared to the females (Table 4.2).

Polydontia of the maxillary and mandibular incisor teeth was observed in the adult pigs. Persistence of the second mandibular incisor tooth (Plate 4.10) was noted in about 42% (n=11) of the pigs; with 64% being males (n=7) and 36% being females (n=4). This persistence occurred bilaterally, in 7 NIPs and unilaterally in 4 (right unilateral=1, left unilateral=3). Only male adult pigs had unilaterally-occurring polydontia.

A deciduous incisor 3 tooth (Plate 4.12) was noted to be persistent on the maxilla of 15% (n=4) of adult pigs examined. This was noted in 50% of adult female NIP (n=2; 1 bilateral and left unilateral, each) and 50% of adult male NIP (n=2; 1 bilateral and right unilateral, each).

About 69.2% (n=18) adult NIPs showed no evidence of erupting the first mandibular premolar (P_1), with equal distribution of the occurrence in both sexes (50% in males and females, respectively). Maxillary premolars were however noticed in all the pigs examined in this study.

Adults NIPs that retained their deciduous third incisor on the maxilla did not erupt the permanent counterparts. Furthermore, two grower males, with broken third deciduous incisors, on the maxilla, showed no evidence of erupting the permanent teeth.

Table 4.2: Mean ± Standard Error of the age of eruption of maxillary and mandibular permanent teeth in the Nigerian indigenous pig

	MALES (n=12)			FEMALES (n=14)		
Tooth	**Number**	**Mean± S. E**	**Range (Weeks)**	**Number**	**Mean± S. E**	**Range (Weeks)**
Man. $\mathbf{I_1}$	8	63.50±2.179	56-67	12	63.00±1.784	56-78
Max. $\mathbf{I^1}$	7	65.43±2.223	59-57	11	65.64±2.487	55-78
Man. $\mathbf{I_2}$	6	91.67±2.974	85-104	5	90.80±1.530	88-95
Max. $\mathbf{I^2}$	5	99.40±2.522	93-106	5	98.60±1.568	95-102
Man. $\mathbf{I_3}$	12	35.17±0.705	32-39	14	34.86±0.478	32-39
Max. $\mathbf{I^3}$	9	38.00±2.075**	32-48	11	47.24±1.520	39-57
Man. $\mathbf{C_1}$	11	41.73±1.646**	35-52	8	48.75±1.612	39-52
Max. $\mathbf{C^1}$	11	42.18±1.710***	33-51	10	51.50±1.035	45-56
Man. $\mathbf{P_1}$	3	35.67±0.667	35-37	5	41.80±2.835	34-48
Max. $\mathbf{P^1}$	11	23.18±0.840	19-29	13	23.62±0.655	21-28
Man. $\mathbf{P_2}$	5	74.20±0.489	73-76	10	75.10±0.822	71-78
Max. $\mathbf{P^2}$	7	71.86±1.164	68-76	8	72.75±1.461	68-78
Man. $\mathbf{P_3}$	7	68.14±1.056	65-74	9	69.67±1.067	63-74
Max. $\mathbf{P^3}$	7	67.00±0.436	65-68	10	68.10±0.900	63-71
Man. $\mathbf{P_4}$	7	67.29±0.420*	65-68	11	69.45±0.637	67-74
Max. $\mathbf{P^4}$	7	70.29±1.426	65-74	10	70.00±1.000	68-74
Man. $\mathbf{M_1}$	12	20.33±0.333	19-22	14	20.64±0.248	19-22
Max. $\mathbf{M^1}$	12	22.92±0.378	21-25	14	22.86±0.345	21-24
Man. $\mathbf{M_2}$	9	53.89±1.306	49-60	10	53.90±1.159	49-62
Max. $\mathbf{M^2}$	7	56.86±0.961	54-61	11	57.27±0.982	51-63
Man. $\mathbf{M_3}$	5	134.60±2.293	129-141	10	137.10±2.656	122-146
Max. $\mathbf{M^3}$	6	133.0±2.463	125-141	8	135.10±2.924	122-146

I^3** P=0.0017, C_1** P=0.0088, P_4* P=0.0244, C^1*** P=0.0002

*****Note: Man.: mandibular tooth; Max.: maxillary tooth

I: Permanent incisor tooth

C: Permanent canine tooth

P: Permanent premolar tooth

M: Permanent molar tooth

1: first tooth in the series

2: second tooth in the series

3: third tooth in the series

4: fourth tooth in the series

The permanent teeth eruption pattern elucidated from this study is as follows:

$M_1 \rightarrow P^1 \rightarrow M^1 \rightarrow I_3 \rightarrow I^3 \rightarrow C_1 \rightarrow P_1 \rightarrow C^1 \rightarrow M_2 \rightarrow M^2 \rightarrow I_1 \rightarrow I^1 \rightarrow P_3/P^3 \rightarrow P_4/P^4 \rightarrow P^2 \rightarrow P_2 \rightarrow I_2 \rightarrow I^2 \rightarrow M_3/M^3$

Using the average time for individual tooth to erupt, the sequence of eruption observed from the study was: Maxillary arch: P^1; M^1; I^3; C; M^2; I^1; P^3; P^4; P^2; I^2; M^3

Mandibular arch: M_1; I_3; C; P_1; M_2; I_1; P_3; P_4; P_2; I_2; M_3

Plate 4.9: Photograph of an adult NIP showing the typical alignment and arrangement of the frontal (rostral) maxillary and mandibular incisors.

Plate 4.10: Photograph of an adult NIP showing the non-alignment of the frontal incisors on the mandible due to persistent deciduous second incisor teeth (arrows).

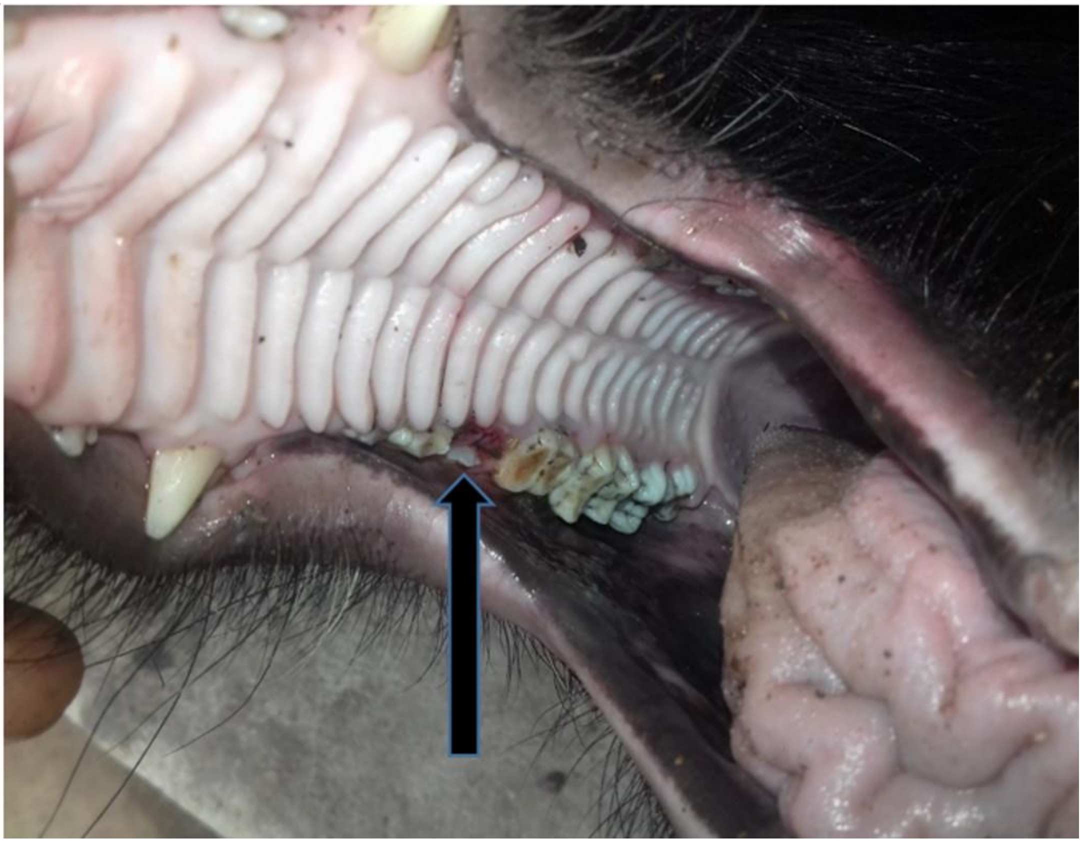

Plate 4.11: Photograph of the oral cavity of a young adult NIP. Note the erupted portion of the crown of the maxillary third premolar tooth.

Plate 4.12: Photograph of the oral cavity of an adult female NIP, with an arrow showing a persistent deciduous third maxillary incisor tooth.

4.1.3 Dental anomalies in the Nigerian indigenous pig

The results obtained from this study revealed that every skull examined possessed a minimum of one type of anomaly. The prevalence of the dental anomalies are stated in table 4.3, age and gender distribution of observed anomalies on the mandibles and maxillae are graphically represented (Figs. 4.1-4.11) while pictorial evidences were illustrated in plates 4.13- 4.21.

4.1.3.1 Dental attrition

Attrition was present in 98% (n=46) of the examined skulls (21 males and 25 females) (Table 4.3; Fig. 4.2). It was present in 100% (n=46) of the mandibles and 96% (n=44) of the maxillae. Across age groups, it was observed in 13% (n=6) of skulls less than 6 months, 35% (6-18 months) and 52% (24-51 months) (Fig 4.1). In total, 267 teeth exhibited evidences of attrition: molar teeth (55), premolar teeth (72), canine teeth (56), and incisor teeth (84). The severity of this pathology was more pronounced in all the premolar, and the first molar teeth (Plates 4.18- 4.21).

4.1.3.2 Dental Calculus

Calculus was observed in 74% (n=35) of the examined skull teeth but was not observed in skulls below the age of 6 months (Table 4.3; Fig. 4.1). Calculus was observed to be more common in female skulls (n=21), than males (n=14) (Fig. 4.3). Teeth of skulls older than 27 months had moderate to severe calculi lesions (premolar teeth were mostly affected). On the affected teeth, calculi lesions adhered firmly to the crowns, coronal to the margins of the gum (Plate 4.20).

4.1.3.3 Fractured tooth

Tooth fracture was observed in 47% (n=22) of the examined skulls (Table. 4.1). 77 teeth showed signs of fracture (19 deciduous, 58 permanent) and they were present on both jaws (n=16, respectively). 6 incisor, 14 canine, 42 premolar and 6 molar teeth were affected (Plate 4.16).

4.1.3.4 Stains

Stains (discoloured teeth) was evident in 96% (n=45) of the skulls examined (Table 4.3) and it was observed in 24 female and 21 male skulls, respectively (Fig. 4.2). Stains were, however, not observed in the skulls of 2 adult females. The extent of stains varied in all the skulls examined, and all the examined teeth appeared to be affected, with variable intensities.

4.1.3.5 Dental caries

Carious lesions were noticed in only two tooth types; the premolar and molar teeth (Plate 4.18). The condition was only observed in the adult skulls (34%, n=16), affecting 34 teeth (Table 4.3; Fig. 4.1). The 4th premolar tooth had the highest incidence of dental caries (n=24), trailed by the 3rd premolar tooth (n=4), the 1st molar tooth (n=3), the 2nd premolar (n=2), and the 1st premolar teeth (n=1), respectively.

4.1.3.6 Tooth rotation

Tooth rotation was observed in 21% (n=10) of all examined skulls (Table 4.3). This anomaly appeared to be more frequent on the maxillary teeth (n=8), when compared to the teeth on the mandibles (n=3) (Fig. 4.8). Only the premolar showed signs of rotation (P1=3, P2=4, P3=2, P4=2, respectively). Unilateral rotation was observed in the skulls and the rotational angle differed, not exceeding 45° (Plate 4.17).

4.1.3.7 Persistent deciduous teeth

It was observed that 23 out of the 24 (96%) matured skulls showed observable persistent (retained) deciduous teeth (Table 4.3). The incisor tooth was the only retained tooth, and it was bilaterally present in 74% (n=17) of skulls affected by this anomaly. In skulls with persistent deciduous incisors, the retained teeth were positioned rostral to the permanent teeth, making contact with the mucosal surface of the lip. The deciduous 2nd incisor tooth was observed to be the most commonly retained incisor tooth (n=25) (Plates. 4.14-4.15).

4.1.3.8 Missing teeth

This study revealed that 31 skulls (66%) showed evidence of missing, at least, a tooth (Table 4.3). 28 skulls (90%) had the first premolar teeth missing while only 3 (10%) had the third incisor teeth missing. The first mandibular premolar tooth was observed to be absent in 70.0% of adult skulls, that were expected to have erupted the tooth

In the male skulls, the first maxillary premolar was observed to be the commonly absent/missed tooth (Plate 4.18), whereas in the female skulls, the mandibular counterparts appeared to be more commonly absent (100%, n=17) (Plate 4.21).

In 75% (n=21) (6 males, 15 females) of the skulls, the first premolar tooth was bilaterally absent. This was observed only on the mandibles. However, a unilateral occurrence of missing premolar tooth was noted in 25% (n=7) of the studied skulls, occurring on both jaws.

3 examined skulls showed evidence of the absence of the third incisor teeth. In 67% (n=2) of the skulls, the third incisor alveolus was not observed (congenital absence) (1 bilateral, 1 unilateral) whereas 33% (n=1) was due to tooth loss (Plate 4.19).

4.1.3.9 Bone resorption

Generalized bone resorption, with varying degrees of severity, was found in 79% (n=37) of all examined skulls, affecting 20 females and 17 males, respectively (Table 4.3; Fig. 4.2). The maxillary bones showed more signs of bone resorption (n=37), when compared with the mandibles (n=28). There were no observables lesions in skulls less than 6 months of age (Fig. 4.1).

Table 4.3: Overview of the total number (n) of affected skulls and prevalence (%) of different dental anomalies in Nigerian indigenous pig skulls.

Dental Anomalies	Number of affected skulls (n)	Prevalence (%)
Dental attrition	46	98.0
Dental calculus	35	74.0
Fractured tooth	22	47.0
Stains	45	96.0
Dental caries	16	34.0
Tooth rotation	10	21.0
Persistent deciduous teeth	23	49.0
Missing teeth	31	66.0
Bone resorption	37	79.0

Note: Table reflects multiple responses

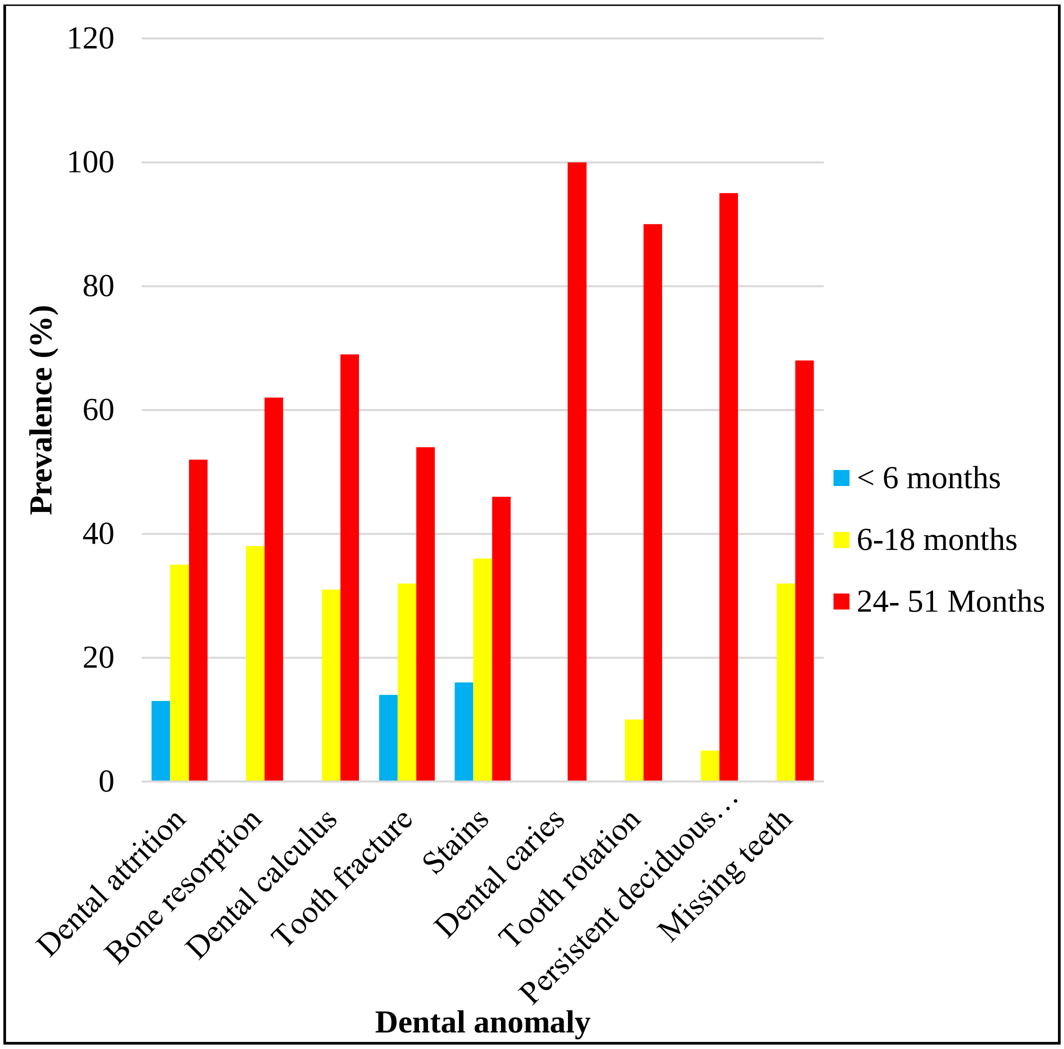

Figure 4.1: Chart showing age-related comparison of the prevalence of dental anomalies in the skulls of Nigerian indigenous pigs.

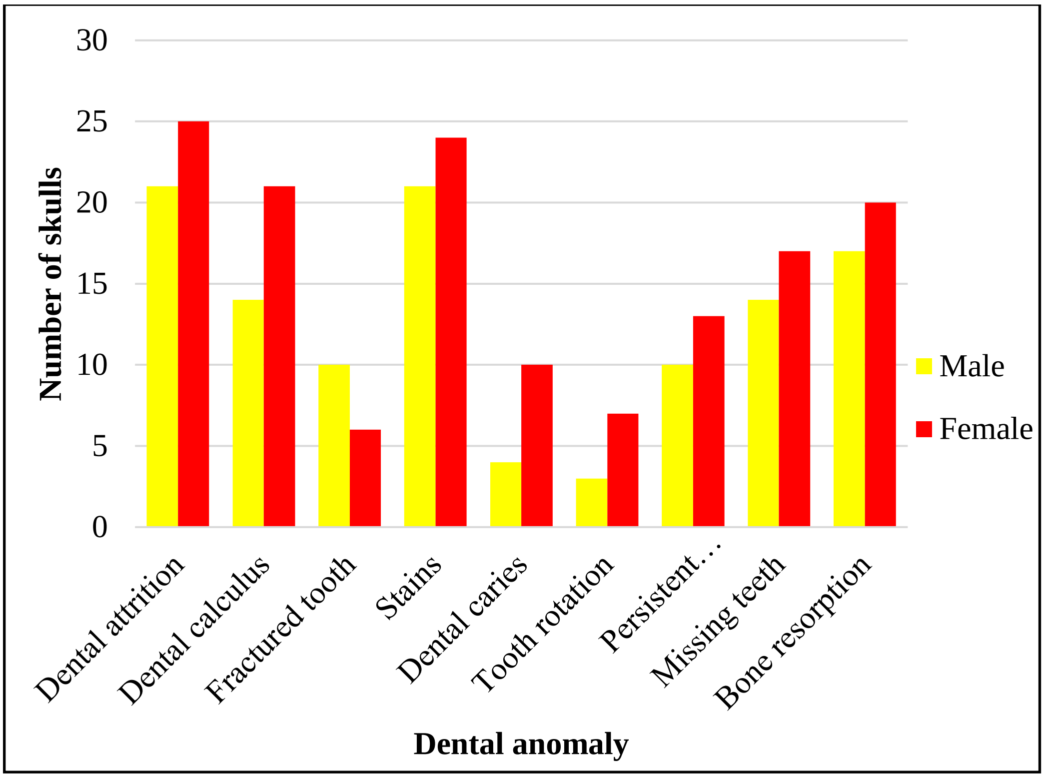

Figure 4.2: Chart showing Sex distribution of dental anomalies in the skulls of Nigerian indigenous pigs.

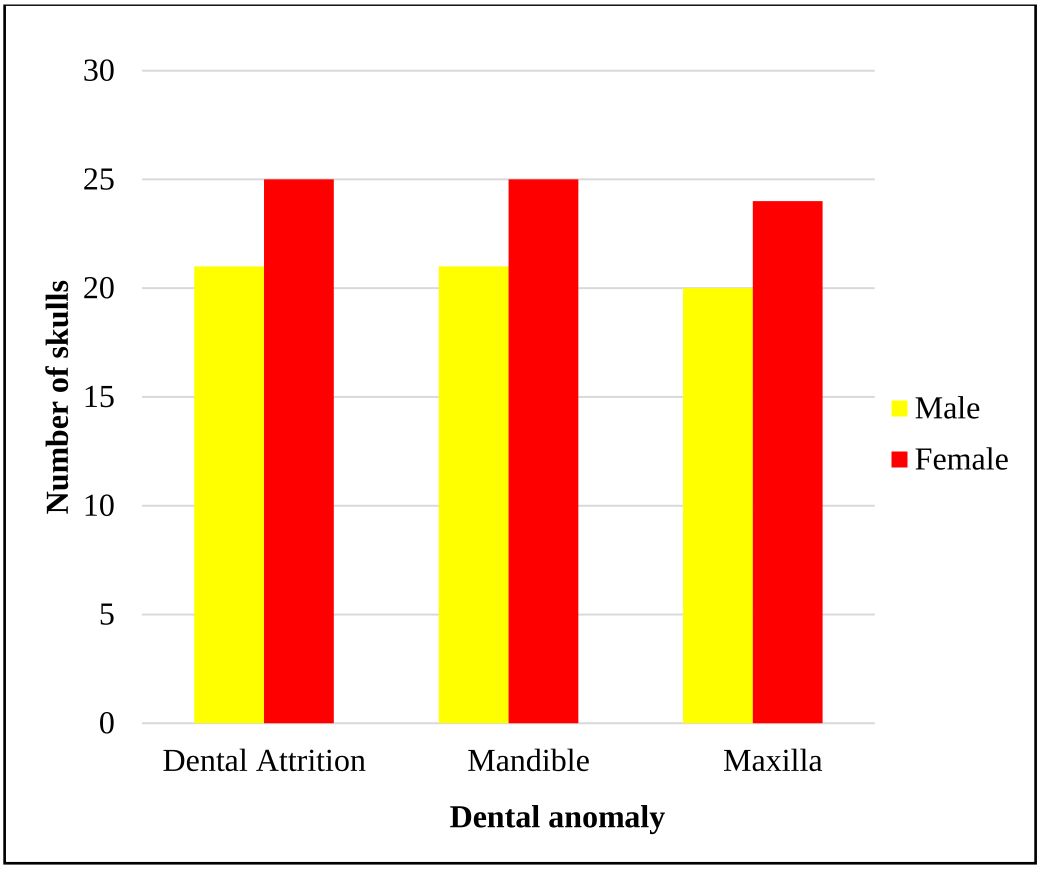

Figure 4.3: Chart showing the distribution of attrition between male and female Nigerian indigenous pig skulls.

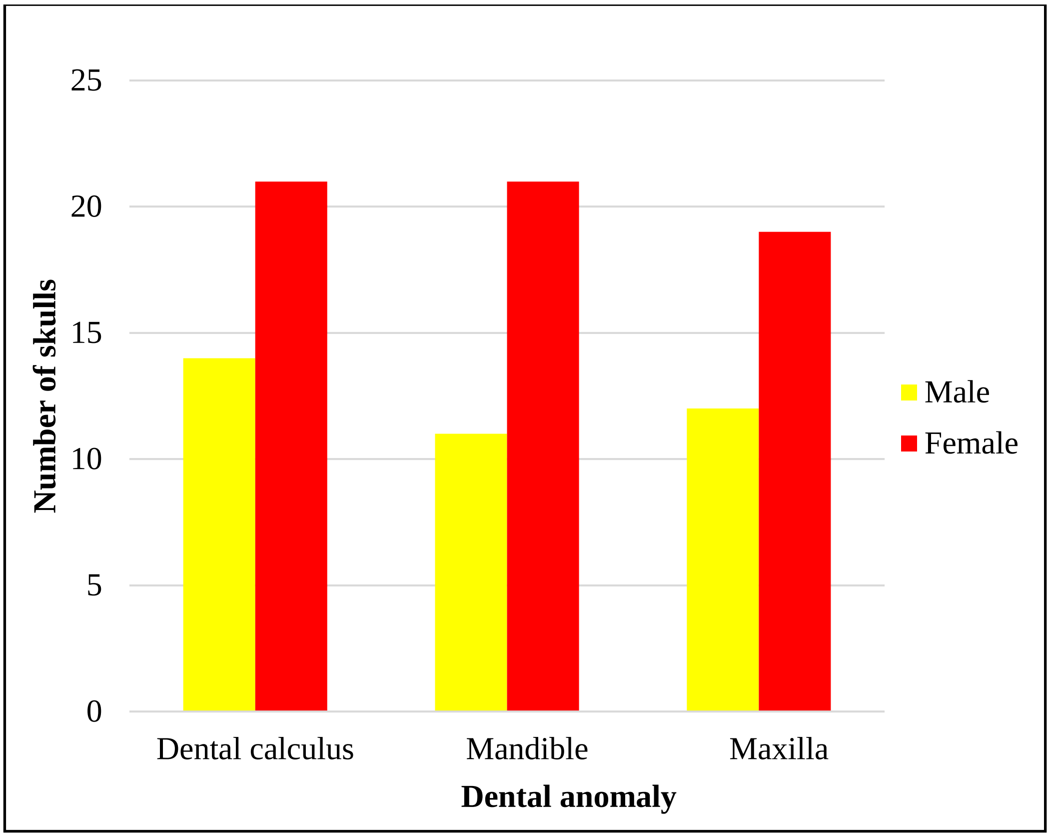

Figure 4.4: Chart showing the distribution of dental calculus between male and female Nigerian indigenous pig skulls.

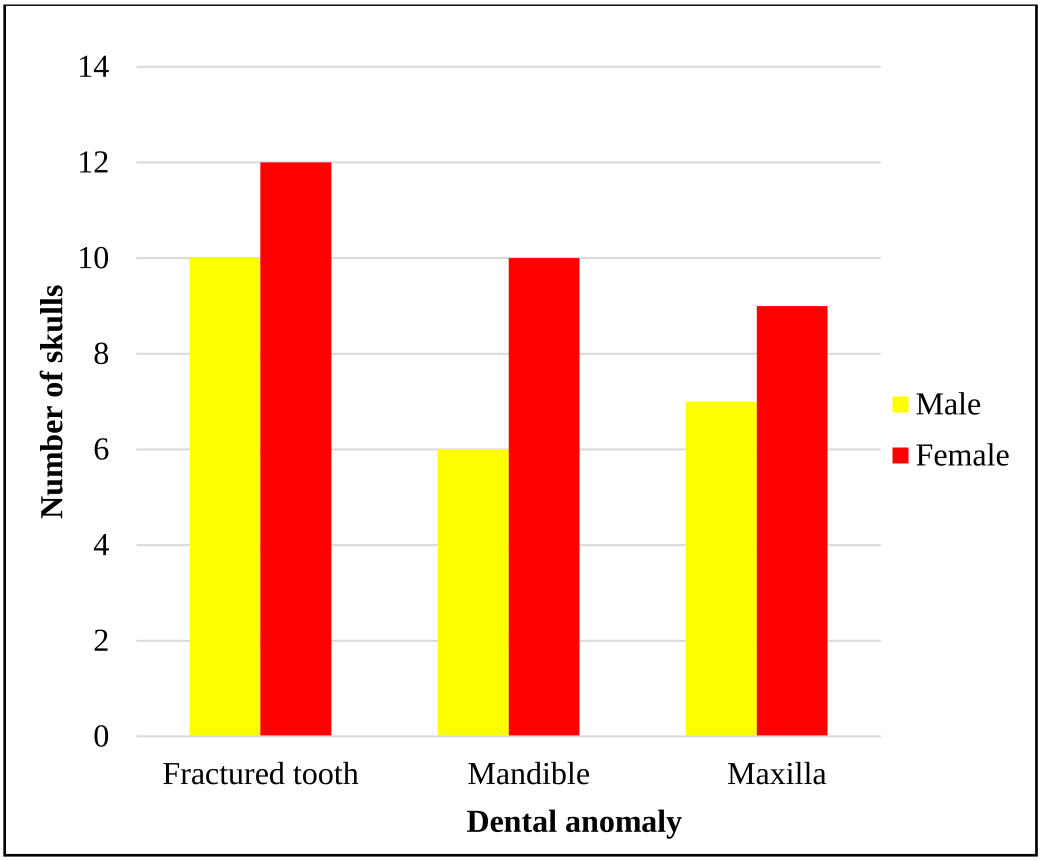

Figure 4.5: Chart showing the distribution of fractured teeth between male and female Nigerian indigenous pig skulls.

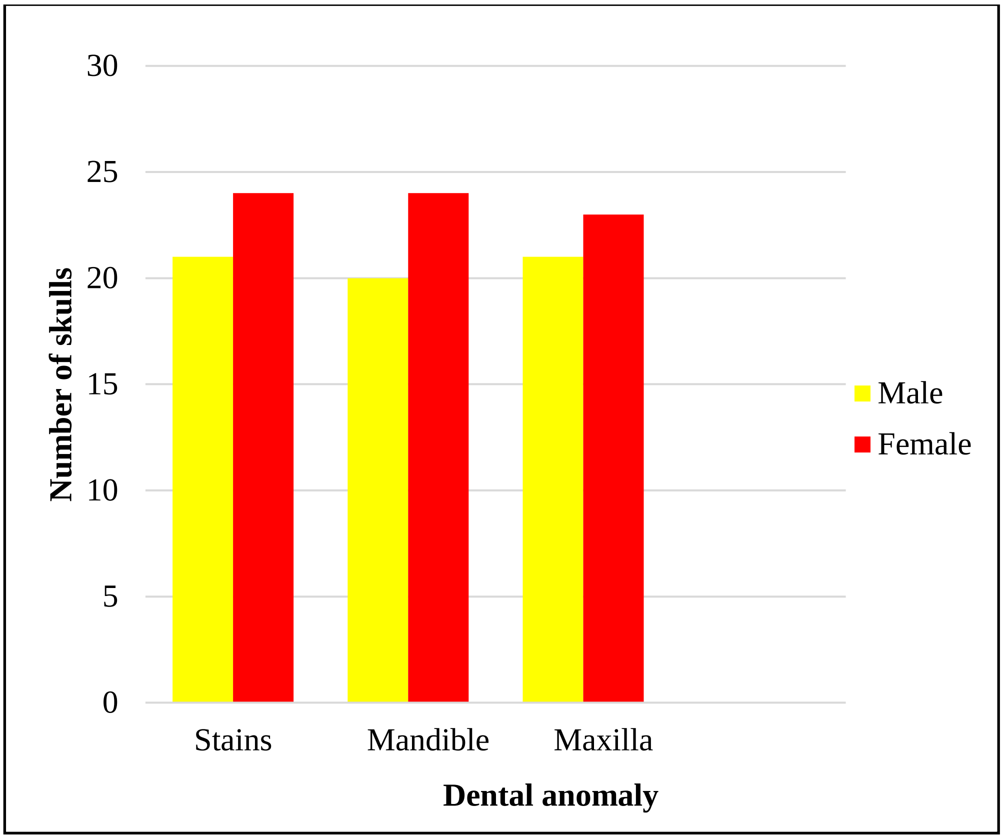

Figure 4.6: Chart showing the distribution of stains between male and female Nigerian indigenous pig skulls.

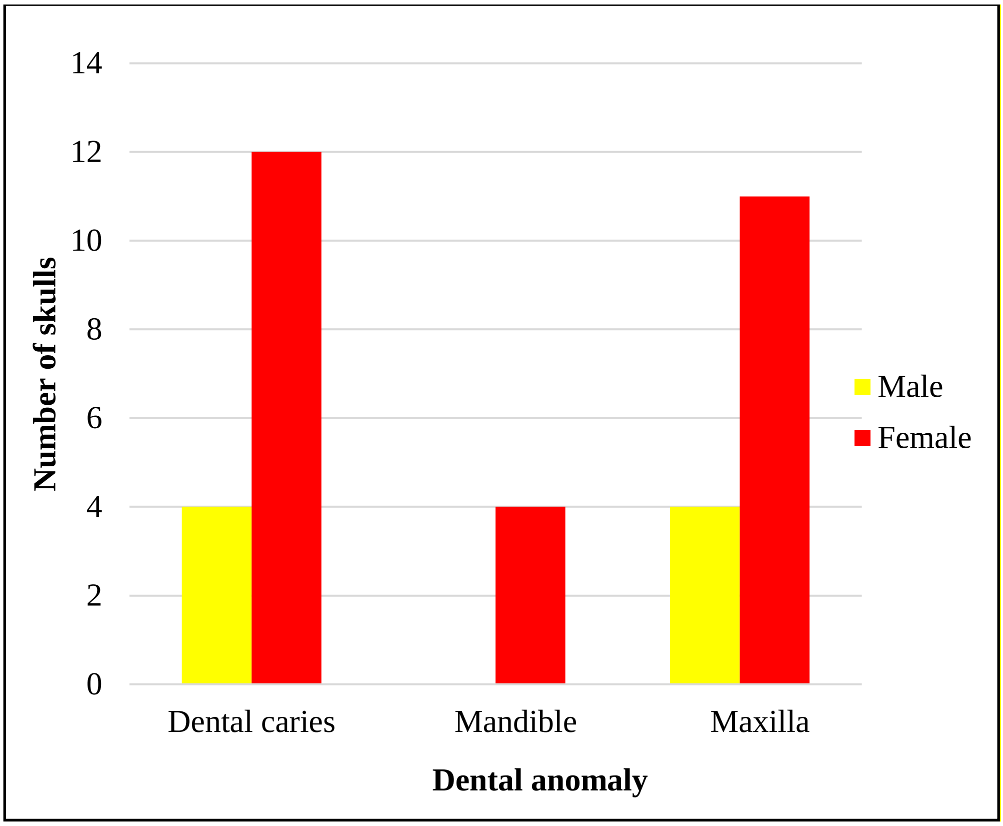

Figure 4.7: Chart showing the distribution of dental caries between male and female Nigerian indigenous pig skulls.

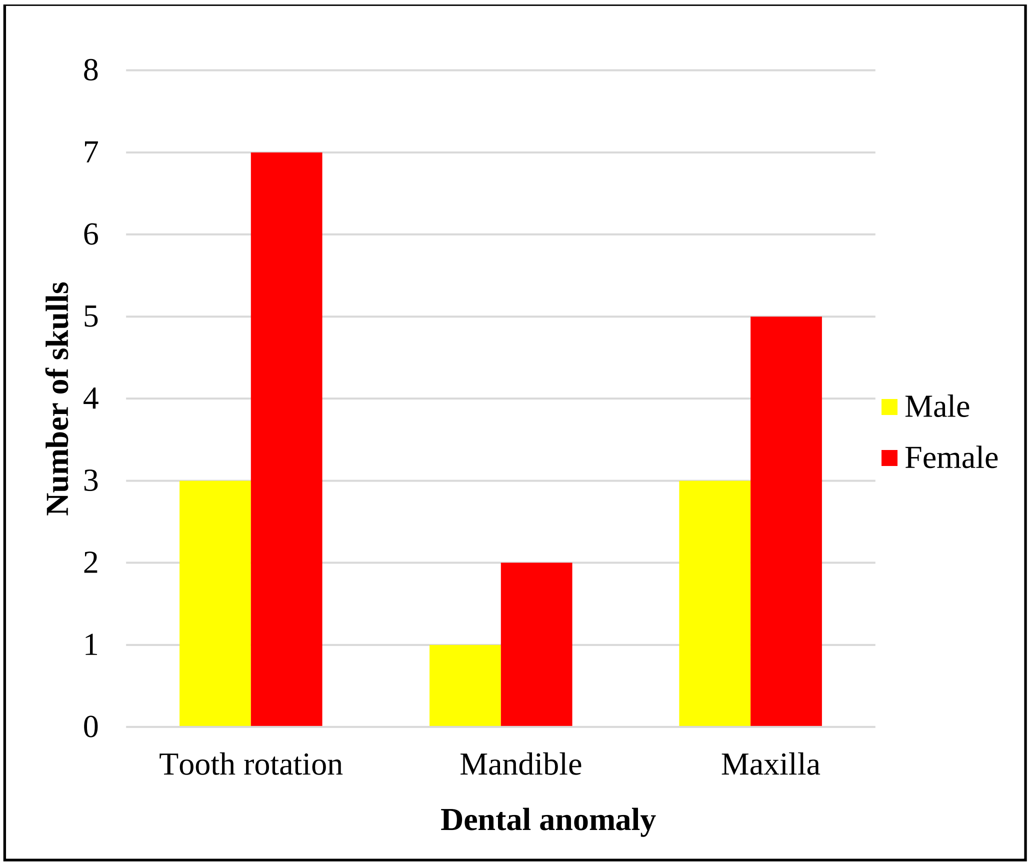

Figure 4.8: Chart showing the distribution of tooth rotation between male and female Nigerian indigenous pig skulls.

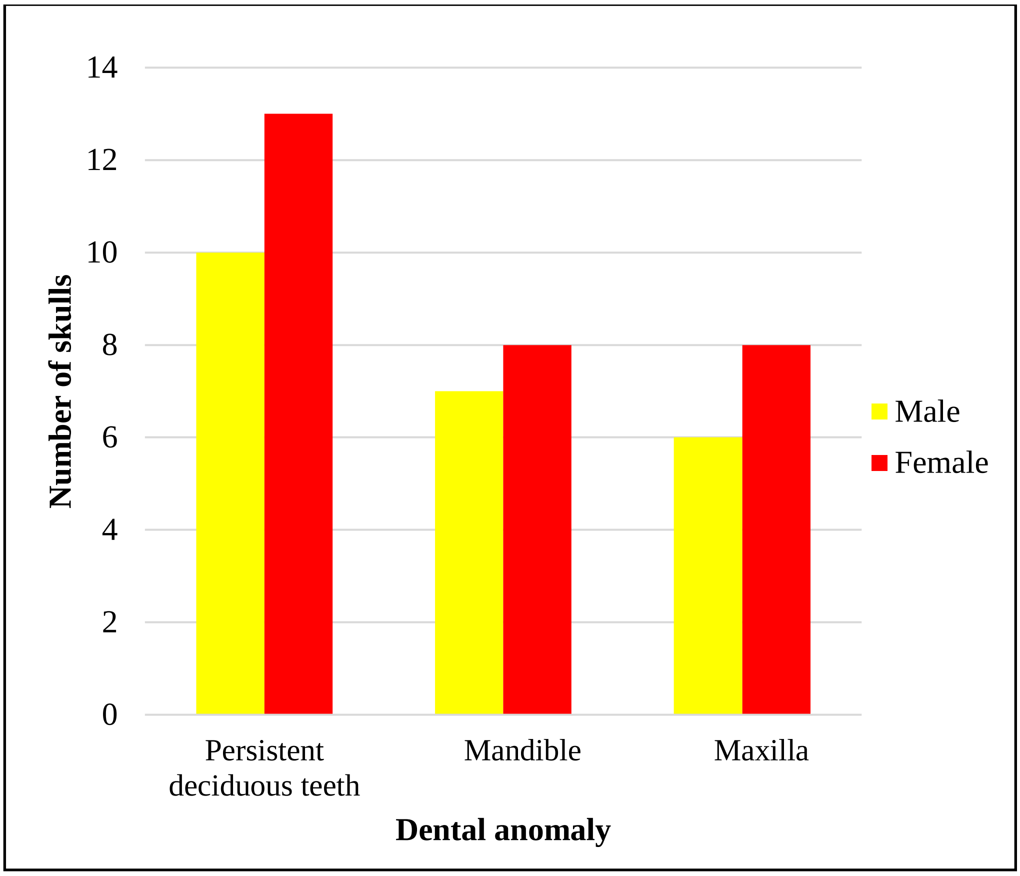

Figure 4.9: Chart showing the distribution of persistent deciduous teeth between male and female Nigerian indigenous pig skulls.

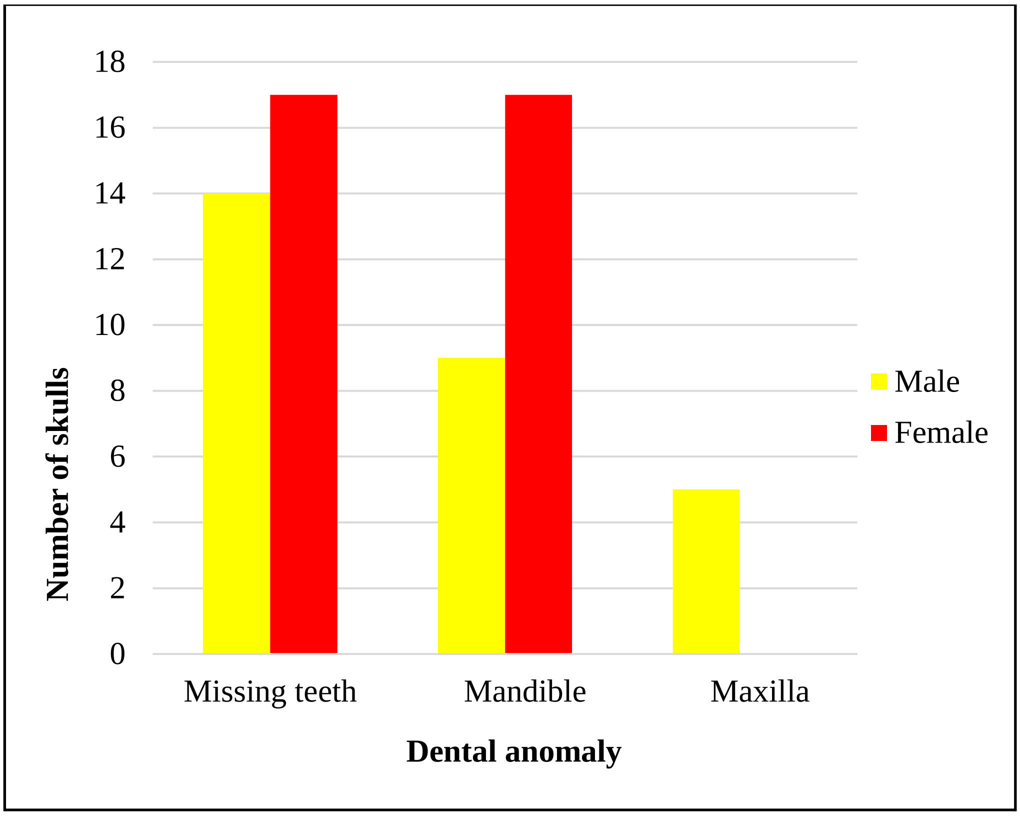

Figure 4.10: Chart showing the distribution of missing teeth between male and female Nigerian indigenous pig skulls.

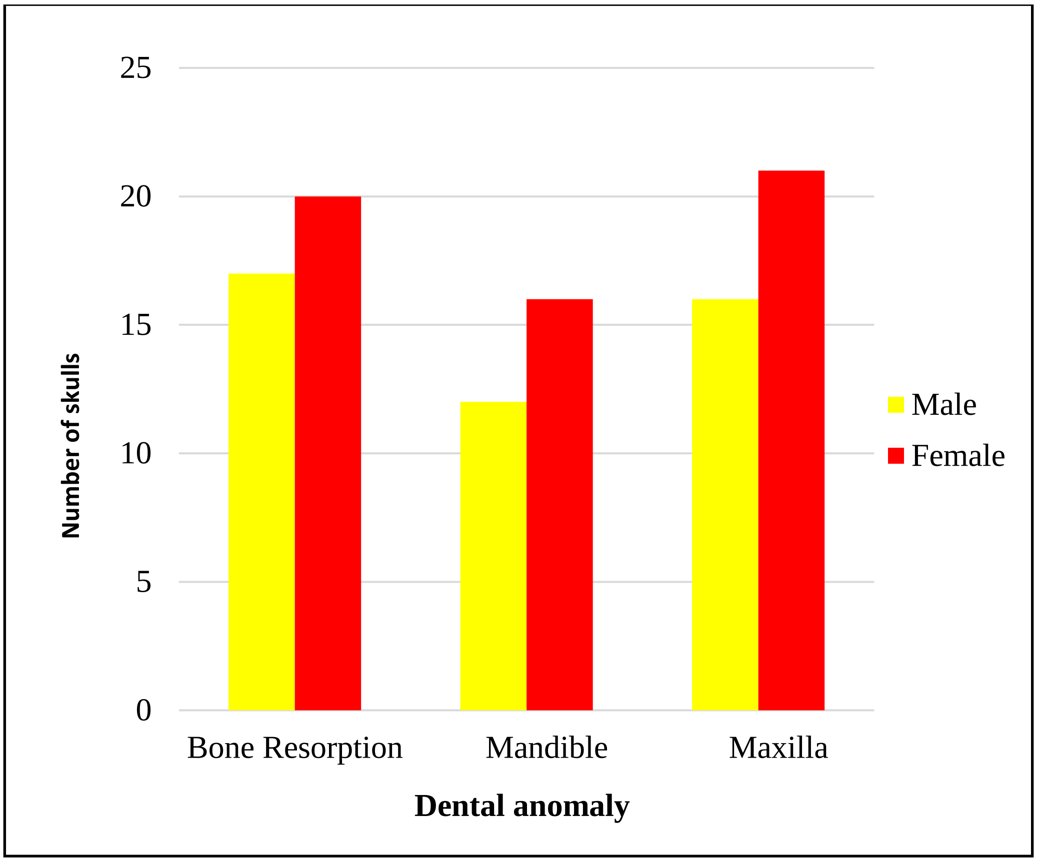

Figure 4.11: Chart showing the distribution of bone resorption between male and female Nigerian indigenous pig skulls.

Plate 4.13: The maxilla of a four-year-old NIP boar showing the regions of severe bone resorption (white arrows).

Plate 4.14: Skull of an adult NIP sow shows a retained deciduous second maxillary incisor tooth (black arrow).White arrow shows the caudal (lingual) dislodgment of the permanent tooth.

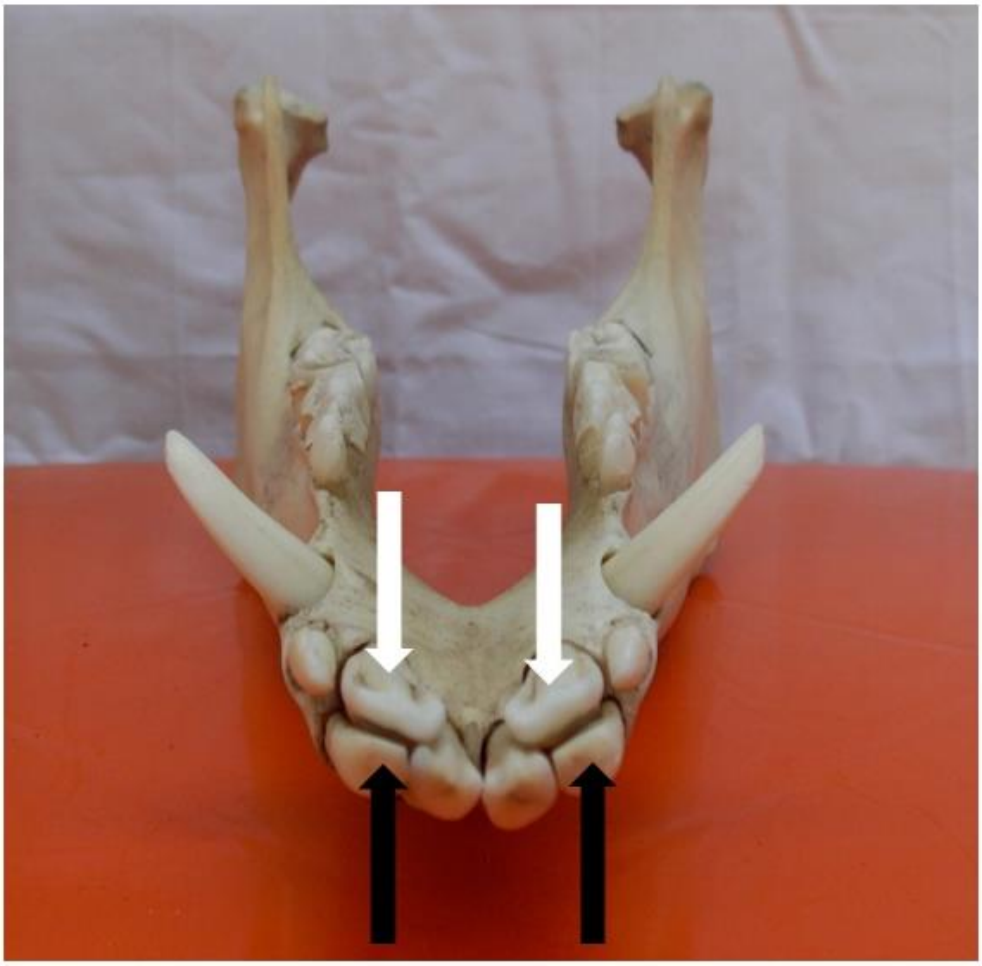

Plate 4.15: Mandible of an adult NIP boar shows retained deciduous second incisor teeth (black arrows) White arrows show the caudal (lingual) dislodgment and misalignment of the permanent teeth.

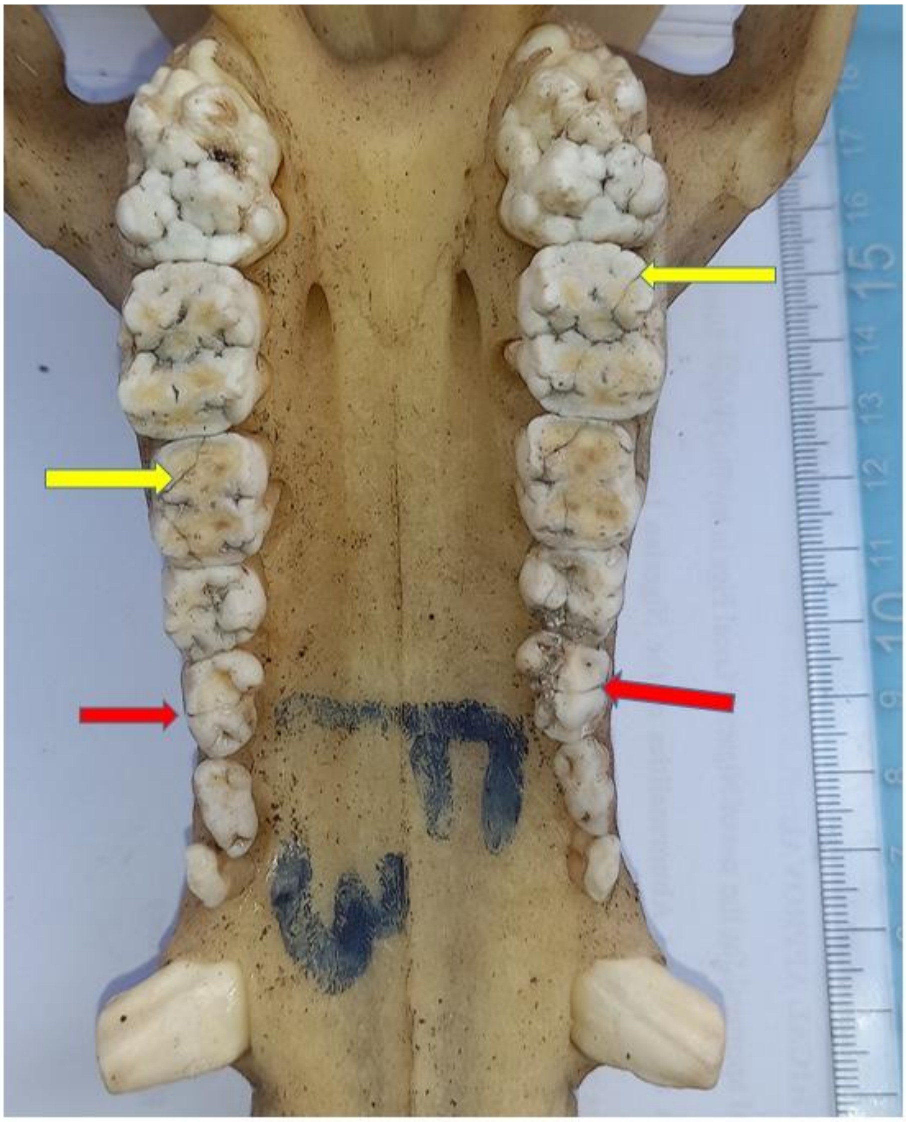

Plate 4.16: Maxilla of an adult NIP sow shows fracture of the third premolar (red arrow), the first, and the second molar teeth (yellow arrows), respectively.

Plate 4.17: Mandible of an adult NIP sow shows counter-clockwise rotation of the fourth premolar tooth.

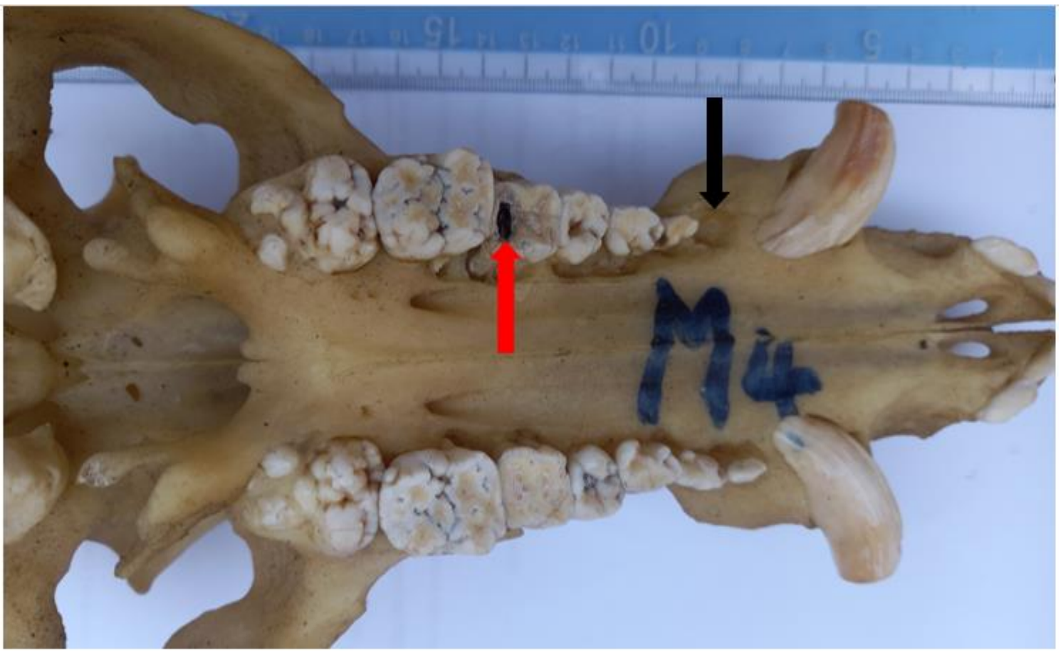

Plate 4.18: Maxilla of a four-year-old NIP boar showing caries on the first molar (red arrow), and an absent first premolar tooth (black arrow).

Plate 4.19: The maxilla of a four-year-old NIP boar showing bilaterally absent incisor teeth (black arrows) and tooth wear of the first molar teeth (white arrows).

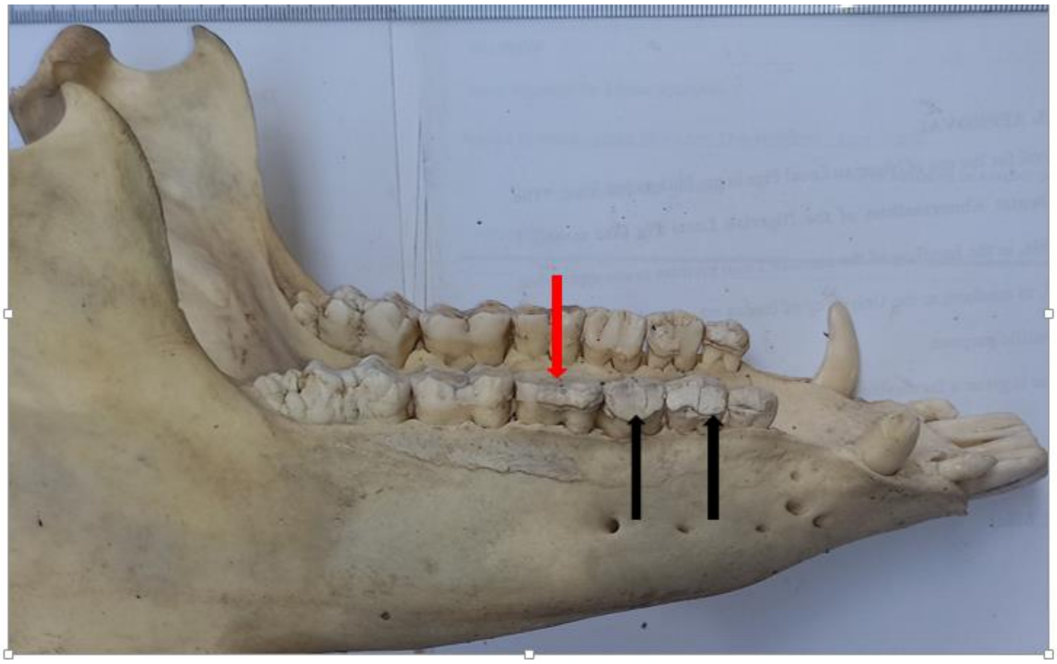

Plate 4.20: Mandible of an adult NIP sow showing calculi on the third and fourth premolar teeth (black arrows), and severe wear of the first molar tooth (red arrow).

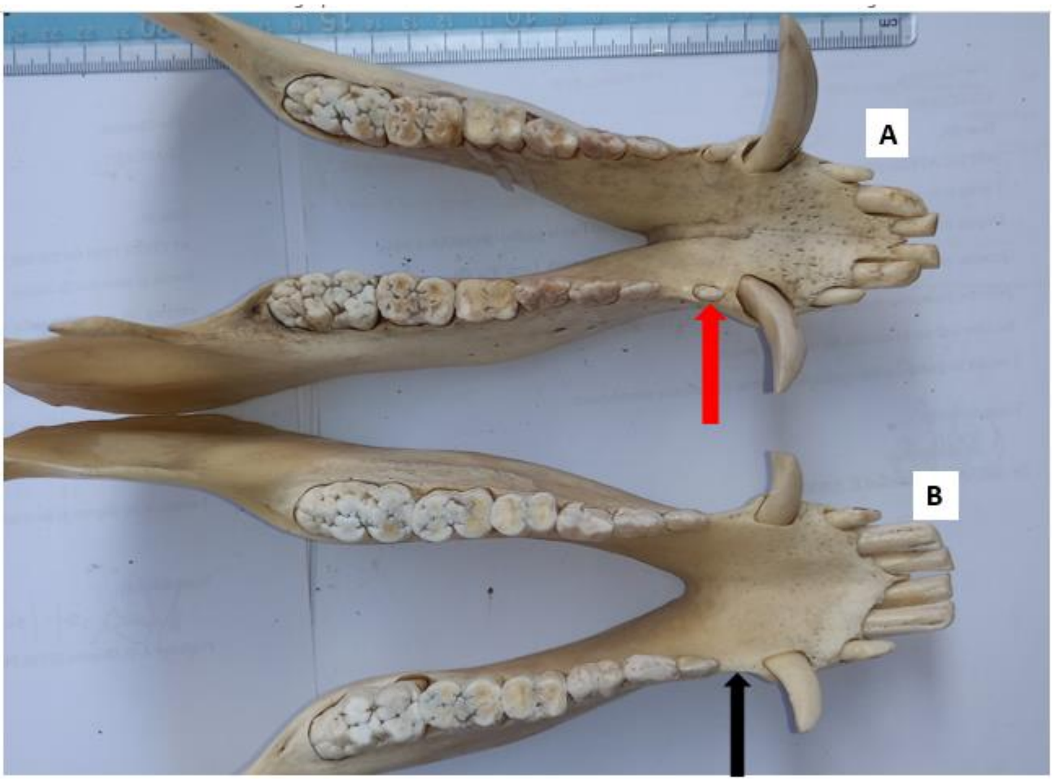

Plate 4.21: Mandibles of two adult NIP sows. (A) Red arrow shows the presence of the first premolar tooth. (B) Black arrow indicates an absent first premolar tooth (diastema).

4.2 DISCUSSION

4.2.1 Deciduous teeth eruption pattern

The dental formula of young, immature Nigerian indigenous pigs (piglets) was observed to be 2(i3/3, c1/1, p3/3) totalling 28 teeth, and is similar to dental formula reported in other breeds of pigs (Weaver *et al.*, 1966; Matschke, 1967; Swindle, 2010). The general timeline of eruption of deciduous teeth in the NIPs appeared to be at variance with what was reported in the European wild pigs (*Sus scrofa*) (Matschke, 1967), the Yorkshire pigs (Tucker & Widowski, 2009), the Large white pigs (Tonge & McCance, 1973) and the miniature breeds of pigs (minipigs) (Weaver *et al.*, 1966; Wang *et al.*, 2007; Swindle, 2010). The variation in the chronology of dental eruptions may be attributed to genetics or the influence of the environment on NIPs (Okandeji, lijoka, Atiba & Olopade, 2021). Tucker & Widowski (2009), noted that livestock production systems and breed selection activities can impact on the commencement of teeth eruptions.

Although the time of eruption of each tooth was not statistically different from one another, female piglets had earlier emergence of the second mandibular incisor, the first incisor, and the third premolar teeth, on the upper and lower jaws. The observation of earlier eruption in the females was comparable to the report of Tucker and Widowski (2009), but dissimilar to the what was reported in minipigs, wherein no sexual difference in eruption pattern was observed in the piglets used for the studies (Weaver *et al.*, 1966). Delay in tooth eruption has been attributed to many causes (Suri *et al.*, 2004), but systemic stress is reportedly the main factor responsible for delayed teeth eruption in the young (Okandeji *et al*., 2021).

Herring and Wineski (1986), established that there exists an interface between tooth growth and development, and mastication in minipigs, while Tucker and Widowski (2009) established that an interaction exits between premolar tooth eruption and the time piglets spent creep feeding, post weaning. Consequently, the outcome of early tooth growth and emergence in female piglets may be an enhanced feed consumption prior to being weaned and possibly, afterwards (Okandeji *et al*., 2021).

Unlike what was reported in Yorkshire piglets, the piglets used in our research displayed a variation in the dental eruption sequence. The emergence of the third mandibular premolar took place before the emergence of the third maxillary premolar tooth, similar to the report of Weaver *et al*. (1966), in the Pitman-Moore minipig. However in the

Yorkshire piglets, the maxillary premolar tooth emerged before the mandibular premolar (Tucker & Widowski, 2009). In addition, the fourth mandibular premolar tooth of the piglets used for our study emerged before its maxillary equivalent. This observation was however different in Yorkshire piglets, where the fourth maxillary premolar tooth was noticed following the emergence of the third mandibular premolar and the first maxillary incisor teeth (Tucker & Widowski, 2009). The emergence of the maxillary first incisor tooth of the NIP piglets was also at variance with the reports obtained in the Pitman-Moore minipig. While the maxillary first incisor teeth emerged after the third maxillary premolar teeth in our study, agreeing with the report in Yorkshire piglets, the incisor teeth of the Pitman-Moore minipigs emerged ahead of the premolar teeth (Tucker & Widowski, 2009). Intra-species eruption sequence is considered a type of adaptation, therefore, an alteration in the sequence of dental eruption might be a pointer to the evolution and environmental adjustments of the breeds of affected species over time (Okandeji *et al*., 2021).

4.2.2 Permanent teeth eruption pattern

The dental formula of mature, adult NIPs was observed to be 2(I 3/3, C 1/1, P 4/4, M 3/3), totaling 44 teeth (Okandeji, Lijoka, Olude, Atiba, & Olopade, 2023b). This observation was consistent with the primitive eutherian number (Zinoviev, 2010; Swindle *et al.,* 2012). The dental formula obtained was also similar to what has been obtained from other breeds of pigs (Matschke, 1967; Weaver *et al*., 1969; Swindle, 2010). In comparison with ruminants, porcine dentition suggests that they are omnivores, which guarantees that they can feed on a wide range of food. It has been established that the mandibular and maxillary incisors occlude when the mouth is closed. In addition to this, the canine teeth appear as elongated, pointed tusks, with the space between cheek teeth and the incisors forming a diastemata (Okandeji *et al*., 2023b).

Permanent dental eruption has been categorized into four general groups: "The first group included only the first molar teeth, while the second general group was made up of the third incisor, canine, and second molar teeth. The third group was almost separated from the others and consisted of the first incisor, and the second, third, and fourth premolar teeth, while the fourth group of teeth to erupt was composed of the second incisor and the third molar teeth" (Weaver *et al.,* 1969). This categorisation was most likely made based on the proximity of the eruption time of individual tooth. This grouping pattern was observed to be similar to what was obtained in our study, with the exception of the emergence of the first mandibular premolar teeth (Okandeji *et al*., 2023b). Weaver *et al*. (1969) did not report the presence of the first premolar on the mandible, hence, it was not categorised. Using the eruption time as a basis of categorisation, the first mandibular premolar teeth in our study would fit into the second general group, because they erupted around the same time with the first molar teeth (Okandeji *et al*., 2023b). Functionally, the first group of teeth provide the temporary premolar teeth with masticatory support, whereas in each of the other groups, incisors and premolars or molars were present, and they are believed to support the functional balance of the teeth (Weaver *et al.,* 1969). The presence of at least two groups of permanent teeth in the mouth results in a mixed dentition which can serve as a guide for age estimation in pigs with unavailable birth records (Okandeji *et al*., 2023b).

Tooth eruption time differed in the pigs used in this research despite the fact that several of them belong to the same litter, and were nurtured under relatively the same conditions. The eruption time recorded for the NIP was at variance with reported observations in domestic pigs, the European wild pigs, the Pitman-Moore mini pigs and the Sinclair mini pigs (Matschke, 1967; Weaver *et al.,* 1969; St Clair, 1975; Gier,1986). Variation in the chronology of dental eruption is considered to be normal, but major deviations should call for concern, as a disruption in the time of tooth eruption might be an indication of a general disorder or a pointer to an alteration in physiology and craniofacial growth (Almonaitiene *et al.,* 2010). Dental eruptive processes may be early or late in pigs, a consequence of alterations in husbandry and breed selection (Tucker & Widowski, 2009). Tooth eruption time may be influenced by the facial and dental arch size, development of the permanent tooth, and diet (Monson & Hlusko, 2018). There appears to be a delay in the emergence of permanent teeth in the NIPs, when compared to the pig breeds mentioned above (Okandeji *et al*., 2023b).

Dental eruption delays may be caused or triggered by multiple reasons. In man, 3 distinctive aetiologies are recognized; the first is associated with any process that causes somatic disruption, such as pain and infectious conditions. The second aetiology is associated with an atypical development of bony component of the oral cavity, whereas the third relates to nutrition-induced pressure on the body system (Tucker & Widowski, 2009). Results obtained from this study revealed that the first mandibular molar tooth erupted ahead of the first mandibular premolar tooth, which was similar to the observations made in the Sinclair miniature pigs. It was observed that the first molar tooth emerged a few weeks ahead of the first premolar tooth (Okandeji *et al*., 2023b). The observations in the NIP was however at variance with the report made in the European wild pigs where the emergence of the molar and premolar teeth occurred almost within the same time interval (Matschke, 1967; Gier, 1986). The delayed dental eruption observed in the NIPs could imply that their maturity may occur later than other breeds of pigs. This delay may have been influenced by genetics or the environment, making them unfit for research works requiring fast maturing breeds (Okandeji *et al*., 2023b).

Although the permanent dentition in the NIPs seem to have emerged much later, when compared to other breeds of pigs, in the males, four teeth had early emergence (the third maxillary incisor tooth, the canine teeth, together with the fourth mandibular premolar tooth). Early eruptions of the canine and the first and third maxillary incisors, together with the canine and the second mandibular incisor, have been described in the males of the Pitman-Moore minipig (Weaver *et al.,* 1969). Mammalian tusks are non-stop, developing (elodont) rostral teeth (incisor and canine) which project from the oral cavity. In wild boars (*Sus scrofa*), tusks are reported to be modifications of the upper and lower permanent canine teeth (Swindle, 2010). Although the canine teeth are more pronounced in mature adult male NIPs, their sizes may disqualify them from being referred to as tusks. Tusks are used as formidable weaponries during fights, for territorial marking of trees in the wild and for lifting heavy object while foraging (Konjević, Kierdorf, Manojlović, Severin, Janicki, Slavica, Reindl, & Pivac, 2006). Female and male castrate pigs have been reported to show a delayed tusks development (Swindle, 2010), consequently, the precocious growth of a boar's canine teeth may be an adaptive feature for survival and a reflection of the hormonal influence of testosterone, regardless of being under captive conditions (Okandeji *et al*., 2023b).

Using the mean eruption time for individual tooth, the sequence of dental eruption noted in the present study revealed that the pattern of eruption of maxillary teeth appeared to be in harmony with that of the mandible. The variation was in the emergence of the lower jaw first premolar tooth, following the canine tooth emergence. The observed variation in the sequence of eruption was attributed to the delay in the emergence of the first mandibular premolar tooth, as against its timely eruption on the maxilla (Okandeji *et al*., 2023b). A descriptive outline of eruption sequence in the Pitman-Moore minipig noted the non-appearance of the first premolar teeth on the maxilla and the mandibular

(Wang *et al.,* 2007). The premolar teeth eruption sequence on both jaws of the NIP was however at variance with what was obtained in the Pitman-Moore minipig. The sequence of eruption of premolar tooth on the lower jaw also varied from what was reported in the European wild hogs' maxillary arch (Matschke, 1967). The sequence of permanent teeth eruption varies across taxa and is strongly influenced by genetics (Monson and Hlusko, 2018).

4.2.3 Dental anomalies profile

Aberrations of the teeth are designated as dental abnormalities or anomalies, and they include abnormal sizes, morphology, numbers, and eruption pattern of teeth (Dwijendra, Parikh, George, Kukkunuru, & Chowdary, 2015). Domestic animals are thought to be more likely to develop specific dental anomalies than their wild counterparts owing to a reduced skull length and the impact of inbreeding (Zinoviev, 2010).

Dental wear or attrition appeared to be the most commonly observed abnormality in the NIP skulls. Dental wear arises from interaction between teeth or crushing actions of opposite teeth (bruxism), resulting in the development of attrition surfaces on the primary surface of enamel (Sperber, 2017). This condition affects both deciduous and permanent teeth and the pattern of dental attrition is most likely determined by the animal species and the morpho-physiological features of different teeth (Kene & Uwagie-Ero, 2001; Malmsten *et al.,* 2015). The high prevalence of tooth wear observed in this study was similar to that of the Swedish wild boars (Malmsten *et al.,* 2015) and the Finnish commercial sows (Ala-Kurikka *et al*., 2019). In this study, the tooth type mostly affected was the first molar tooth. This pattern is similar to what was described by Samuel and Woodall (1988) and Malmsten *et al*. (2015). The first molar teeth are thought to be the first permanent teeth to emerge, subjecting the teeth to increased dental wear. This increased dental wear is as a result of a prolonged stay in the mouth, in comparison to other tooth types, accounting for the level of molar wear observed in this study. In contrast, the frequency of dental wear was highest in the incisor teeth, when compared with the rest (Okandeji, Akinlosotu, Omotosho & Olopade, 2022). Sun *et al*. (2017), reported a similar prevalence pattern in a study conducted in Beijing, China, and postulated that the incisor tooth's thick enamel might be responsible for this observation. Additionally, the deciduous and permanent incisor teeth have an early emergence into the oral cavity, they are therefore exposed to dental wear over a longer period of time, like the molar teeth. Johnson, Curtis & Ellis (2003) concluded that attrition of the molar teeth was concomitant with ageing, while attrition of the incisors may possibly be attributed to several pen-related factors, including nibbling and gnawing at pen doors or other metal structures. Advancing tooth wear may lead to pulpitis and may ultimately result in periodontitis, causing discomfort in the mouth, loss of function and possibly, loss of affected tooth, in the affected animals (Malmsten *et al.*, 2015; Ala-Kurikka *et al.*, 2019).

A prevalence of 34% was observed for dental caries in our study, being greater than the 2% described in wild pigs (Horwitz & Davidovitz, 1992), 11% described in the Swedish wild boar (Malmsten *et al.*, 2015) and 5% prevalence in the Swedish commercial pigs (Malmsten *et al.*, 2020). This reported prevalence may well arise from an inherent vulnerability of Nigerian indigenous pigs to the disease. It could also be due to dietary influence. Carious lesions were not seen in the skulls of piglets from this research but it has been described. Tucker and Widowski (2009), noted that numerous piglets displayed discoloured teeth post farrowing and such piglets subsequently showed carious lesions. The observation might be associated with some pre-natal conditions, as the manifestation of dental caries within weeks of post-natal life denotes the insufficient *in-utero* deposition of enamel (Okandeji *et al*., 2022). During odontogenesis, the dentine is overlaid by the enamel, and this arrangement ensures that the dentine is protected from the effect of nutrition and the environment. Any deficiencies of the enamel are therefore long-lasting, reducing the efficiency of disturbed tooth, and resulting in suboptimal growth of affected animals, as a possible outcome (Tucker & Widowski, 2009; Tucker *et al.*, 2011).

Dental calculus, a hard calcified plaque, was noticed in 74% of the skulls examined in our research. The observation was greater than the 11% in commercial sows in Sweden (Malmsten *et al.*, 2020), and 40% in Swedish wild pigs (Malmsten *et al.*, 2015). These hard deposits, classified as supragingival calculi, were located on the crowns of the affected teeth, coronal to the margin of the gum. The distribution of calculus has intra-species, tooth to tooth and surface to surface variations (Aghanashini *et al*., 2016). Calculi accretion occurs in relation to an animal's age (Kyllar & Witter, 2005), and this was apparent in our study, where it was noticed that older skulls had more deposits on their teeth, whereas teeth of piglets were devoid of such deposits. Varying degrees of calculi deposits appeared to be associated with the premolar teeth, in the adult skulls. This observation was comparable to the findings in Swedish wild pigs, with 93% of seriously impacted teeth being the premolar teeth (Malmsten *et al.,* 2015). It implies that the development of dental calculus is a step-by-step disorder and teeth that are infrequently utilised for masticatory functions are susceptible to the development and deposition of dental plaque (Okandeji *et al*., 2022).

Typically, teeth are made up of numerous colours and colour gradation are seen between the margin of the gum and the tooth crown. The margin of the gum is reportedly darker in colour, owing to its closeness to the dentine. Most times, the canines appear darker than the incisor teeth (Watts & Addy, 2001; Mortazavi, Baharvand, & Khodadoustan, 2014). These characteristic differences in colour could also influence the thickness and translucency of the enamel and dentine (Sulieman, 2005). It has been reported that the older a person gets, the darker the teeth become, a phenomenon attributed to the lay down of secondary and tertiary dentine, absorption of pigments and a progressive enamel degradation which permits an impact on the colour of the underlying dentine (Watts & Addy, 2001; Mortazavi *et al.,* 2014). In humans, teeth discolouration has been categorised as “intrinsic staining”, “extrinsic staining” or "internalized discolouration", subject to its depth of infiltration in a tooth. (Mortazavi *et al.,* 2014; Tucker *et al.,* 2011). The observable dental colourations or stains in our study skulls may be attributed to any of the categorisations above.

Discoloured deciduous teeth, after birth, may be caused by intrinsic (innate) or extrinsic (acquired) factors. The presence of discoloured needle teeth in some piglets, few days after farrowing may be attributed to causative factors while the piglets were in the uterus (Okandeji *et al*., 2022). Innate discolouration of tissues that take part in the development of the teeth often happens when tooth development commences *in-utero* and causes of such staining include many metabolic illnesses, increased consumption of fluoride, tetracycline, vitamin D deficiency, or any disruption of the process of normal laydown of enamel or dentine (Tucker & Widowski, 2009).

Fractured tooth, also called tooth crack, is a discontinuity in the dental enamel, dentine or cementum and it is considered to be a medically significant challenge, with many predisposing factors (Lynch & Mcconnell, 2002). The 47% prevalence of tooth fracture reported in our study was above the 41% of Swedish commercial sows with the same condition (Malmsten *et al.,* 2020), the 25% reported in Finnish commercial sows (Ala-Kurikka *et al.,* 2019), the 22% reported in domestic pigs (Smith *et al.,* 2020), and the

8% reported in Swedish wild pigs (Malmsten *et al.*, 2015). Even though fractures have been categorised according to location and type, as either complete or incomplete fracture (Ellis, 2001), the dental cracks reported in our research were not categorised. In Sweden, the incisor tooth was reported to be the tooth with the highest frequency of fractures in wild and domestic pigs (Malmsten *et al.*, 2015, 2020). This observation was different from what was obtained in our study, where the molar and incisor teeth had the lowest frequency of fractures (8%), whereas the premolar teeth had the highest frequency of 55%. In the porcine species, the morphology of the teeth, the dietary and behavioural practices, and additional violent behaviours, could dispose a particular tooth to the condition (Malmsten *et al.*, 2015). Dental caries has also been incriminated as a possible aetiology for the vulnerability of teeth to fractures (Soares *et al*., 2017), therefore, a prevalence of 34% for carious lesion, reported in this study, may have contributed to the development of the observed dental fractures. Similarly, the incidence of tooth fracture increased as the animals got older, suggesting that permanent teeth are likely to be more susceptible to dental traumas, including fractures (Okandeji *et al*., 2022). It has also been reported that root fracture can occur as a sequelae of the fracture of the tooth itself and this should be taken into consideration when treating tooth fractures (Malmsten *et al.*, 2015).

Rotation of a tooth is described as the dislodgment of a tooth from its typical orientation on the dental arcade. It has been associated with dental overcrowding, on the jaws, owing to hereditary factors like length and size of a skull, or to environmental factors like serious undernutrition. The overcrowding may lead to dental malocclusion and asymmetry on the mandible and the maxilla (Horwitz & Davidovitz, 1992; Binois *et al.*, 2014; Okandeji *et al*., 2023a).

This study revealed that about 21% of the pigs used for the study had signs of displaced teeth. This observation was similar to the 20% prevalence in wild boars but greater than the 10% observed in domesticated pigs, respectively (Feldhamer & McCann, 2004). Our observation was also greater than the 10% observed in feral pigs and 13% in bush pigs (*Potamochoerus spp*) respectively (Horwitz & Davidovitz, 1992). Rotation was also observed to be more frequent on the upper jaw, affecting just the premolars. This observation was comparable to the reports of Horwitz and Davidovitz (1992) and Feldhamer and McCann (2004). As a result of the absence of observable indications of excess numbers of teeth on the upper and lower jaws in the pigs used for this study, the observed rotations may be due to a shortening of the mandibles and maxillae or may be because of the comparative dimensions of the teeth. This might eventually lead to irregular wear patterns resulting from misalignment and malocclusion of affected teeth (Okandeji *et al*., 2023a).

Despite the fact that all animal species have specific dental formulae, intra-species deviations have been known to occur (Binois *et al.*, 2014). Teeth variations like missing tooth and extra tooth have been reported for domesticated and feral pigs (Feldhamer & McCann, 2004; Malmsten *et al.*, 2015).

Supernumerary teeth, (hyperdontia or polydontia), is a departure from the complete eutherian number, occurring in nearly all vertebrate species, which includes humans (Okandeji *et al*., 2023a). It is assumed to be a congenital condition and may arise from the duplication of dental tissues due to the cleaving of dental follicles, arising from increased activity of the dental lamina, resulting in the development of additional dental buds (Okandeji *et al*., 2022). It is characterised by the presence of at least two teeth, which are usually identical. This condition occurs in positions where only one tooth should be present, and can be located anywhere on the dental arcade within the mouth (Lin, Chang, & Lin, 2009; Zinoviev, 2010; Binois *et al.*, 2014; Malmsten *et al.*, 2015). Polydontia sometimes presents as a retained deciduous tooth, and this was noticed in this study. As a result of space insufficiency, a supernumerary tooth may undergo rotation or a displacement to an unusual position on the dental arch. This event then results in dental overcrowding or malocclusion (Garvey, Barry, & Blake, 1999; Okandeji *et al*., 2022, 2023a).

A deciduous tooth is considered to be persistent if it is retained within the oral cavity beyond its time of exfoliation and replacement (Okandeji *et al*., 2022). With good crown, roots, and supporting alveolar bone, it can sustain its masticatory function in adult life (Aktan *et al*., 2012). Typically, the roots of a deciduous tooth become gradually resorbed at the onset of the emergence of the succeeding permanent tooth. However, the deciduous tooth root resorption is a process that can occur even when the permanent successor is absent (Kjær, Nielsen & Skovgaard, 2008; Aktan *et al.*, 2012). Developmental absence of a permanent successor, impacted tooth, atypical positioning and delayed emergence of replacement tooth, are some of the reasons implicated in the retention of a deciduous teeth (Aktan *et al.*, 2012; Deepa, Rana, & Arun Kumar, 2016).

The present study showed that 78% of the adult skulls retained deciduous incisor teeth, occurring more in the female skulls. About 74% of these skulls showed evidence of bilaterally retained deciduous teeth. In these instances, the second deciduous incisor tooth was the most frequently observed tooth. The observed persistent deciduous incisor was comparable to the report of Johnson *et al*. (2003), who noted persistent deciduous incisor teeth in about 15% of the matured sows examined. A similar observation was made by Smith *et al*. (2020), who stated that of all the domestic pigs observed in their study, 43% of them retained their deciduous teeth, with the second upper incisor tooth having the highest frequency of retention. For the retained deciduous teeth observed in this study, (skulls older than 24 months), only 10 pig skulls were not up to 3years. Thus, using reported data on eruption as a reference (Matschke, 1967), the deciduous dentition observed in our study pigs may be considered as being persistent or retained. The persistence of deciduous dentition might be due to a failed or botched emergence of the permanent counterpart, as against the suggestion that it is the cause of the emergence (Okandeji *et al*., 2022). Retained deciduous dentition, in human population are thought to lead to some medical conditions such as periodontal disease, severe carious lesions, visual and phonic challenges (Deepa *et al.,* 2016). Persistent deciduous teeth can also lead to excess numbers, improper alignment and articulation of the teeth within the oral cavity, uneven dental attrition, dental caries and eventually, periodontal disease, triggering oral pain and discomfort (Malmsten *et al.,* 2015). Periodontal disease and its attendant effect arise from the impact of reduced interdental spaces and abrasive effects of food particles and fibres, leading to the infection of the surrounding gum.

The term ‘hypodontia’ generally refers to the absence of at least one tooth, either in the deciduous or permanent dentition. This usually happens as a result of a loss due to extraction or because of a deviation during odontogenesis. In human populations, this condition is believed to be the craniofacial abnormality with the highest frequency of occurrence. It may occur as an infrequent event, or as part of a genetic, or independent non-genetic syndrome (Wu, Wong, & Hägg, 2007; Klein *et al*., 2013; Al-Ani *et al*., 2017; Okandeji *et al*., 2022).

The condition can be categorized into two: true hypodontia (congenitally absent) or false hypodontia (absent due to post-eruption loss or exfoliation) (Malmsten *et al.,* 2015). Potential causes of “missing” may include a congenital absence, (hypodontia or oligodontia), precocious shedding, leading to tooth loss, and fracture beneath the gum

(Arte & Pirinen, 2004). Absent teeth are frequently observed in the permanent or adult dentition. They are not noticeable or may not be evident in immature animals, since they just have deciduous or temporary teeth (Al-Ani *et al.*, 2017). Absent teeth are only visible in adulthood, when the deciduous teeth ought to have been exfoliated and succeeded by the permanent teeth. It should be noted that whenever a deciduous tooth is absent due to congenital defects, its permanent replacement may also be absent (Pavlica *et al.,* 2001; Klein *et al.,* 2013; Shokri *et al*., 2015; Al-Ani *et al.,* 2017).

This present study, involving live pigs, revealed that 69% of the NIPs failed to erupt the first mandibular premolar tooth, occurring equally in both sexes, whereas, examination of macerated skulls revealed that 66% of them missed a tooth or more. The first premolar tooth was missing in about 90% of them, while only 10% did have any evidence of the third incisor tooth. The observation was comparable to the report of Malmsten *et al*. (2015) on feral swine in Sweden, who reported that missing teeth was the commonest teeth abnormality, present in 69% of the pigs observed. In one of the pigs in their study, all teeth with the exception of the canine, and the first and second incisor teeth, in both jaws, were absent. This condition, called "Hypohidrotic Ectodermal Dysplasia" (HED) in humans, has been described in the canine and bovine species (Lewis, Reiter, Mauldin, & Casal, 2010). Malmsten *et al.* (2020), reported that, in a research conducted on 58 sows, 59% of them had a minimum of one tooth being absent and half of the missing teeth were the premolars. Another study reported that 50% of domestic pig skulls and 23% of the skulls of wild pigs showed signs of missing teeth, with oligodontia as the frequently observed abnormality. Over 20 of the affected skulls had missing first lower premolars on the mandible (Feldhamer & McCann, 2004).

Even though we were unable to perform any radiographic investigation on the skulls used for this study, the availability of numerous observations of absent premolar teeth on the mandibles of feral and domesticated swine confirms the findings from the present study. The variability of its location, coupled with how it erupts and its comparative separation from the other premolar teeth on the mandible could influence the incidence of its absence on the lower jaws (Feldhamer & McCann, 2004). Considering the position of the first premolar tooth, hypodontia might suggest a tendency towards a decrease in the number of teeth on the dental arch of placental mammals (Zinoviev, 2010). The fact that the first premolar tooth on the mandible is commonly absent might suggest that it doesn't have functional significance, with reference to mastication, in older and matured pigs. On the other hand, non-existent first premolar and third incisor teeth, on the upper jaw, may be due to exfoliation, as a consequence of periodontitis (Okandeji *et al*., 2022).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

The dental eruption patterns and the profile of dental anomalies of the NIP were studied in a group of NIPs. The deciduous dental eruption pattern and sequence was investigated, over a period of 24 weeks, which was the time it took for the Nigerian indigenous piglets to complete their deciduous eruption. Similarly, the permanent dental eruption pattern and sequence was also investigated in adult NIPs, between 18 and 148 weeks, which was the time interval for the commencement and completion of the eruptions, respectively. In addition to the investigation of the dental eruption in this breed of pigs, the profile of dental anomalies was also investigated. This research also considered age and sex-related differences in the patterns of eruption and the incidence and prevalence of the observed dental anomalies.

This work, to the best of my knowledge, is the first to be reported in the Nigerian indigenous pigs, concludes that the timing and sequence of dental eruption, and the profile of dental anomalies observed were different from what has been reported in other breeds of pigs. Therefore, the data provided, from this study are expected to be useful in comparative anatomical, dental and epigenetics studies. This work also offers baseline information on the profile of dental eruption and dental anomalies of this breed of pig and such information can be used for future dental studies on the NIPs. It will also be of great interest to pig farmers. Dental eruption and health affects feeding, therefore the understanding that slight delays in dental eruption may occur prepares the farmer for such occurrences and possible interventions. Data provided will also be useful to Nigerian researchers using pigs as translational research models, as they are able to accurately estimate the ages of pigs to be used as research animals.

5.2 CONCLUSIONS

This research work has been able to describe and show that:

I. The sequence and timing of deciduous dental eruption obtained from this study varied from what has been reported in other breeds of pigs.

II. The eruption of deciduous tooth in the NIPs showed the presence of sexual variations.

III. The sequence and timing of permanent dental eruption obtained from this study varied from what has been reported in other breeds of pigs.

IV. Sexual variations also existed in the dental eruption time of the permanent teeth.

5.3 RECOMMENDATIONS

1. Further research should be conducted to determine the incidence and prevalence of dental anomalies in food animals in Nigeria. It is imperative to identify the factors that might impact tooth eruption and the categories of disorders or anomalies that may impact pigs and other food animals, the vulnerable age brackets, the regularity of manifestation, as well as the factors that influence such disorders or anomalies.
2. Thorough and periodic oral examinations should be included in the routine health care programmes of food and companion animals as timely detection of oral and teeth disorders may aid increase in production and can help promote productivity and decrease financial deficits.
3. Veterinary dentistry should be incorporated into the Veterinary curriculum (postgraduate level and the College of Veterinary Surgeons) and Veterinary practice in Nigeria as part of routine health care).

5.4 CONTRIBUTIONS TO KNOWLEDGE

This study has been able to establish the following in the Nigerian indigenous pig:

1. The needle teeth and first molar tooth, are the first set of deciduous and permanent teeth to erupt, respectively.

2. The elucidation of the sequence and pattern of the eruption of deciduous teeth, which was completed within 24 weeks.

3. The elucidation of the sequence and pattern of the eruption of the permanent teeth, which was completed by the 146^{th} week, thus providing a template for ageing in the Nigerian indigenous pig.
4. The documentation of the profile anomalies of the teeth, in the Nigerian indigenous pig. The skulls were aged 3 months to 51 months (12 to 204 weeks).

5.5 FURTHER RESEARCH

One of the limitations of this study was the inability to use radiographic techniques to further strengthen the understanding of the dental eruption processes, due to its unavailability. Radiographic examination of live pigs and macerated skulls will provide additional information on the eruptive processes taking place within the jaws, especially in animals that either didn't erupt the premolar tooth or those that had retained deciduous tooth.

Another area of future research is the environmental influence on dental anomalies in the NIP. It is important to know what role, if any, does metal concentration in the teeth or skulls bones play in the development of dental anomalies. Are there modulators of odontogenesis that are influenced by the environment?

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APPENDICES

APPENDIX I

PUBLICATIONS

1. **Okandeji, M. E.,** Lijoka, A. D., Olude, M. A., Atiba, F. A. and Olopade, J. O. (2023) Permanent tooth eruption patterns in Nigerian local pigs. *Journal of Veterinary Dentistry*. First published online January 31, 2023. DOI: 10.1177/08987564231152390.
2. **Okandeji, M. E.,** Lijoka, A. D., Atiba, F. A., Adebiyi O. and Olopade, J. O. (2023) Dental disorders in wild and domestic pigs (*Sus scrofa*): a review**.** *Journal of Veterinary Dentistry*, 40(1): 47-56. DOI: 10.1177/08987564221125398.
3. **Okandeji, M. E**., Femi-Akinlosotu, O.M., Omotosho, O. O. and Olopade, J. O. (2022). Dental pathologies in the Nigerian local pigs (*Sus scrofa*) *Archives of Anatomy and Physiology* 7 (1):001-008. DOI: 10.17352/aap.000019.
4. **Okandeji, M. E**., Lijoka, A. D., Atiba, F. A. and Olopade, J. O. (2021). The eruption patterns of the teeth of Nigerian local pigs (*Sus scrofa*): profile of deciduous teeth. *Journal of Veterinary Anatomy*, 14 (2): 1-15. Doi: 10.21608/jva.2021.197235.

APPENDIX II

LETTER OF AWARD

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Michael Efeturi OKANDEJI,
Department of Veterinary Anatomy,
Faculty of Veterinary Medicine,
University of Ibadan,
Ibadan.

Dear Okandeji,

Award for Publication of Articles from Ph. D Thesis

Greetings.

I write on behalf of the Postgraduate College Board to award you a prize for the publication of the following article from your Ph.D Thesis during the 2021/2022 session.

Title: **"Permanent Tooth Eruption Patterns in Nigerian Local Pigs".** *Journal of Veterinary Dentistry.* First published online January, 2023. DOI: 10.1177/08987564221125398. Published by SAGE Publishing (Impact Factor 1.154, indexed in Scopus).

The prize carries a monetary value of ₦25,000.00.
It is my hope that you will continue to strive for excellence.
I am by this letter requesting the Bursar to prepare the prize in like sum in your favour.

In light of the above, the Awardee is expected to write to the Deputy Bursar, Postgraduate College, University of Ibadan stating the account to be credited for the monetary value of the award.

Please accept my best wishes.

Sincerely,

Professor A. S. O. Ogunjuyigbe, *R.Eng*

cc: Vice Chancellor
Deputy Vice-Chancellor (Academic)
Dean, Faculty of Veterinary Medicine
HOD, Department of Veterinary Anatomy
Sub-Dean, Faculty of Veterinary Medicine
Deputy Bursar, Postgraduate College
Deputy Provosts, Postgraduate College