BIOMETRIC AND MORPHOLOGIC CHARACTERISTICS OF THE SKULL OF THE GWEMBE VALLEY DWARF GOAT (*Capra hircus*) BREED OF ZAMBIA

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A thesis submitted to the University of Zambia in fulfillment of the requirements of the degree of Master of Science (MSc) in Veterinary Anatomy and Physiology

THE UNIVERSITY OF ZAMBIA
SCHOOL OF VETERINARY MEDICINE
BIOMEDICAL SCIENCES DEPARTMENT
LUSAKA

DECLARATION

I **Andrew Kataba** do hereby declare that the work presentation in this thesis represents my own work carried at the School of Veterinary Medicine, University of Zambia. The work has not been submitted previously for the award of a degree or any other qualification at this or another University.

Signature: --------------------- **Date: -----------------**

CERTIFICATE OF APPROVAL

This thesis by **Andrew Kataba** has been approved as fulfilling the requirements for the award of the degree of Master of Science (MSc) in Veterinary Anatomy and Physiology by the University of Zambia.

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Supervisor Signature

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ABSTRACT

This study gives the first morphometric description of the skull of the Gwembe Valley Dwarf (GVD) goat, the applied regional anatomy of the head region as well as the gross morphology of this indigenous goat breed of Zambia. The dearth of information on the cranial morphometry, applied anatomy of the head region and general morphology on domestic animals and the indigenous goats in particular was the motivation behind this study. Thirty heads (15 male and 15 female heads) were collected from purposively and randomly sampled GVD goat aged 18 months and above from a slaughter slab and processed for cranio-morphometry investigation. Forty three morphometrical measurements were recorded from each of the 30 skulls. From these, simple descriptive statistics, multivariate statistics, craniofacial indices, and the coefficient of variation analyses performed and obtained. Further, the variance of the skull structure was determined using a Principal Component Analysis (PCA). The comparative craniometry analysis of the male and female skulls was also carried out. Additionally, twelve measurements of some clinically important landmarks around the skull useful for regional anesthesia in the mandibular regions of head were taken on all 30 skulls and summarized using descriptive statistics. The gross morphology or the macro-anatomy of the general skull of this breed was equally noted.

The skull length and skull breadth were 15.02 ± 1.09 cm and 8.14 ± 0.39 cm, respectively. According to the results, the GVD goat breed can be classified as mesocephalic (cephalic index 54.4 ± 3.37), and mesoprosopic (facial index 58.5 ± 3.46); and orbits were rounded (orbital index 99.10 ± 0.08).The skull length and the skull breadth of the GVD goat were positively correlated to the facial index ($p < 0.025$) at 95% significance level (two-tailed). On the other hand the skull length was negatively correlated to the cephalic index. The results from Principal Component Analysis indicated that skull variance was concentrated on the first two principal components. The first principal component explained only 34.2 % of the generalized variance in skull parameters while the first three principal components explained 56% of the variance. The analysis (PCA) did not give any special emphasis to a particular variable. Broadly

speaking, the skull variation in GVD goat was centred on total variation in shape of the skull.

A Non-Parametric One-way Analysis of Variance (NPMANOVA) test with Mahalanobis distance reflected no differences between male and female skulls from the general skull parameters ($F=1.104$, $p=0.317$), and significant difference ($p<0.05$) between male and female goat skulls based on the horn parameters ($F=4.752$, $p=0.006$) was observed.

The distance between the lateral ends of the alveolus of the incisor tooth to the mental foramen was 1.58 ± 0.19 cm. The length and maximum height of the mandibles were 11.24 ± 0.52 cm and 6.64. ± 0.44 cm, respectively. The distance from mandibular angle to below of mandibular foramen was 1.21 ± 0.08 cm, while the distance from the mandibular foramen to the base of the mandible and mandibular angle to below mandibular foramen were 2.35 ± 0.26 cm and 1.10 ± 0.07 cm, respectively. These results are of clinical importance and aid in regional nerve blocks of the infraorbital, mental and mandibular nerves.

From the gross morphological examinations of all the 30 skulls of the GVD goat, it was observed that morphologically, sexual dimorphism was evident in the frontal bone with the frontal eminence being more prominent in males than females. Accessory supraorbital foramina were observed in some skulls irrespective of the sex.

This study has described the biometric and the morphologic characteristics of the GVD goat and concludes that a contribution for comparative model for other African local caprine breeds in general and Zambian caprine breeds in particular has being made. Being the first study of its kind in Zambia, it makes a significant contribution to a better understanding of the GVD skull typology. It is envisaged that the results obtained in this study will be useful as baseline research data in comparative goat neuroanatomy and neuropathology. The result further provides a valuable reference data for regional anaesthesia of the head region in Gwembe Valley Dwarf goat breed.

DEDICATION

This thesis is dedicated to:

My lovely wife Sandra and our precious daughter Lushomo,

For their love, support and understanding

My Uncles, Mr. R. Kataba and Mr. G Samusale

For believing in me

My friends

For making everything worthwhile

ACKNOWLEDGEMENTS

This research would not have been possible without the financial support of the University Of Zambia through the Staff Fellow Development Office.

Great appreciation goes to my supervisors namely Dr. E.S MWAANGA, Prof. P.M. PARÉS and Dr. H. SIMUKOKO, for their contribution in ensuring that this work was completed.

I am also very grateful to the technical staff in the Department of Biomedical Sciences of the Samora Machel School Veterinary Medicine at the University of Zambia for their assistance. To the local farmers from Siavonga and the Manager for the livestock section at Chibolya market, I remain indebted for their help and cooperation in the acquisition of fresh heads of the indigenous Gwembe Valley Dwarf goats.

I shall forever be grateful to my family for their patience, care, love and support during the period of study.

I am eternally grateful to God Almighty for giving me wisdom and guidance that enabled me to complete my research work.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Percentage
<	Less than
>	Greater than
^{o}C	Degree Celsius
°	Degree
-	Negative
=	Equals
/	Per
Kg	Kilogram
mm	Millimetre
cm	Centimetre
m	Meter
n	Number
min	Minimum
Max	Maximum
SD	Standard deviation
SE	Standard error of the mean
CV	Coefficient of Variation
PAST	Paleontological Statistics Software Package for Education and Data Analysis
PC	Principal Component
PCA	Principal Component Analysis
Yr	years
rho	Spearman’s Rho Correlation

CHAPTER ONE

1.0 INTRODUCTION

Domesticated goats (*Capra aegagrus hircus*, sometimes referred to as *Capra hircus*) belong to the family *Bovidae,* sub family *Caprinae* and to the genus *Capra.* This genus is composed of nine species including wild goats (*Capra aegagrus*), markhor (*Capra falconeri*) and other species known as the *ibex* (Ansell, 1972; Payne and Wilson, 1999). Along with sheep, goats were among the first domesticated animals. The domestication process started at least 10,000 years (calibrated calendar years) ago in what is now northern Iran (Zeder and Hesse, 2000). Easy human access to goat hair, meat, and milk were the primary economic indicators to motivate for the domestication process (Payne and Wilson, 1999). Goat skins were popularly used until the Middle Ages for water and wine bottles when travelling and camping, and in certain regions as parchment for writing (Crabtree *et al.*, 1989).

The goats found in Zambia today are believed to have been acquired from the Matebele and Shona kingdoms of the present day Zimbabwe (Mwenya, 2001). The numbers in the national flocks are not well documented because traditionally, census priority is given to cattle. The national goat- herd is widely distributed in the country, but due to the goat's ability to survive under harsh environmental conditions, they are largely confined to the drier areas such as the Gwembe and Luangwa valleys. Although there are many indigenous goat breeds in Zambia, with a few exotic breeds, like the Boer goat (Mwenya, 2001), no information regarding their morphological characteristics is documented.

Animal morphology shows considerable variation with respect to breed, age, sex, nutritional condition and environmental factors among others (Alpak *et al*., 2009). Thus, measurements are important tools for comparison. In order to achieve a more objective assessment, numerous metrical measurements need to be carried out (Künzel *et al*., 2003; Brombin *et al*., 2009).

Although, the shape and appearance of the head is important in determining the nature of an animal (Dyce *et al*., 2002), but only a few morphometric characteristics of the skull have been documented for the goat (Olopade., 2003; Olopade and Onwuka ., 2005a ;2009; and Zvychainaya and Puzachenko ., 2009). Data generated from skull biometry can be important in anthropology (Bokonyi, 1974), forensic studies (Adebis, 2009), regional anaesthesiology (Olopade and Onwuka, 2005a), taxonomy (Habel, 1975) and comparative anatomical studies between and within breeds (Olopade *et al*., 2006a). They are also important for classification, as the phenotypic appearance of an animal's head has been reported to depend on the shape of the skull and is strongly related to breed-specific skeletal features (Künzel *et al*., 2003).

The paucity in the knowledge of cranial morphometric of indigenous Zambian goats dictated the need for this scientific study. This study focused on indigenous goats owned by villagers in Siavonga district in the Zambezi Valley and the plateau of the Southern Province, which is one of the districts with the largest number of goats in Zambia (Lundu *et al.*, 2012). Morphological characteristics of the skulls from these goats were studied and the results analysed statistically. This study envisaged to advance the understanding in the knowledge of skull biometry and evolutionary biology of the indigenous Zambian goats.

1.1 Study justification

Goats in Zambia and other parts of Southern Africa have been described based on the external morphological characteristics such as the general body size, coat colour, and nature of the ears or tail (Payne and Wilson, 1999). There is however need to add to this existing description, the internal detailed anatomical aspect. Therefore, this study seeks to include the craniometrical description to the already existing external morphological approach. Craniometrical studies have been carried out on Carnivores (Onar, 1999) and small ruminants (Borthakur *et al.*, 1998) and other similar studies were carried out on the Zambian mole-rat (*Fukomys mechowiis*) by Chimimba *et al.*, (2010). However, no skull biometry data is available on Zambian goat breeds and in particular the indigenous Gwembe Valley Dwarf goat. Hence, our study is designed to record the biometry of various skull parameters in the Gwembe Valley Dwarf goat breed. The data generated from this work will be the first of its kind in Zambia as such it will serve as baseline data on the Gwembe Valley Dwarf goat and will be useful in craniometrical comparative study of Zambian goats in future. Furthermore, the information may also be useful in forensic studies. Adebis (2009) reported that data obtained from biometrics has been a valuable tool in anthropology and forensic science. Additionally, the applied clinical anatomy of the Gwembe Valley Dwarf goats results arising from the research will provide information to the veterinary surgeons on relevant, local features (anatomical information) peculiar to these local goats that can be used in regional anaesthesia (Uddin *et al.*, 2009).

1.2 Study objectives

1.2.1 General objective

The general objective of the study was to determine the cranial morphometric measurements, morphology and applied clinical anatomy of skulls of the Gwembe Valley Dwarf goat breed of Zambia.

1.2.2 Specific objectives

The specific objectives of the study were as follows:

1. To generate craniometrical data for the skull of Gwembe Valley Dwarf goat breed.
2. To create baseline data of the Gwembe Valley Dwarf goat that will be useful in comparative anatomical studies between species of domestic animals and also between and within breeds of goats.
3. To establish a reference data base useful for anatomical landmarks used in regional anaesthesia of the head of local goats (Gwembe Valley Dwarf goat).
4. To investigate some gross morphological characteristics of the Gwembe Valley Dwarf goat skull.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and distribution of Zambian goats

The indigenous goats found in Zambia are believed to have been acquired from the Matebele and Shona kingdoms of the present day Zimbabwe (Mwenya, 2001). While goats are widely distributed throughout Zambia, over 60% are in the river valley areas and semi-arid regions (CSO, 1997). These areas are characterised by poor crop production and often cannot support cattle production due to trypanosomiasis and feed scarcity (Ahmadu *et al*., 2000; DAPH, 1993). These drier areas include the Gwembe and Luangwa valleys (Mwenya, 2001). There are many indigenous goat breeds in Zambia and some exotic breeds, largely the Boer and the Saanen goats. The Boer goat was introduced in 1999 from South Africa with the view of enhancing productivity of local goat breeds through the production of bucks with higher meat production potential (GART, 2007). The Saanen goat is being promoted as a dairy breed among small scale farmers. This breed has been imported from East Africa (Kenya and Tanzania) into the Zambia (MACO, 2003).

A 2003 estimate showed the population of goats in Zambia to be about 2 million with 95% of these being owned by traditional farmers (DVLD, 2003). However, more recent reports on goat population showed a marked decline in the population. Currently there are about 759,000 goats in the national flock with Southern Province contributing to the highest number (DVLD, 2009).

2.2 Types of goats found in Zambia

In Zambia, indigenous goats are classified by the locality where they are predominantly found. For instance, in the Southern half of the country, three different breeds have been identified. These are:

1. **The South East African Dwarf Goat type or Gwembe goat**: This is a small sized goat mainly found in the Gwembe valley. This goat breed has adapted to

hot and dry climatic conditions with low rainfall patterns. There are variations in coat colour of this breed ranging from black, brown, black and white, grey to white and brown. The horns are of medium size and curved backwards (MACO, 2003; Chisanga and Mwenya, 1998).

2. **The Valley goat**: It is found in most of the southern half of the country and the northern parts of the Zambezi escarpment and Luangwa valley. This is generally a larger goat and has a variety of coat colours, white, black, brown and grey as the main colours and a combination of these colours is not uncommon (MACO, 2003; Chisanga and Mwenya, 1998).

3. **The Plateau goat**: This breed is found on the plateau areas and widely distributed in the country. Colours vary from black, brown and roan with or without white markings. The goats are short with fine and glossy coats (Chisanga and Mwenya, 1998).

In the recent past, a number of exotic breeds have been introduced into the country by Non Governmental Organisations (NGOs), private individuals and farmers. These breeds have high performance traits with respect to meat and milk yield. The introduced exotic breeds include:

1. **The Boer goat:** This is an exotic meat breed from South Africa. This breed was introduced to Zambia in 1999 under the Boer goat project whose objectives were to explore ways and means of increasing the rate of multiplication of the Boer goat herd; and enhancing productivity of local goats through the provision of bucks with higher meat production traits (GART, 2007).

2. **The Saanen goat**: This is the dairy breed that is being promoted among the small scale farmer groups in Zambia. It was imported from East Africa (Kenya and Tanzania) into Zambia (MACO, 2003)**.**

2.3 Socio-economic importance of goats

Goats are very useful animals and are used for diverse purposes in different parts of the world. These include meat, milk, mohair fibre production, cheese production, and skins for leather making. Meat production is the major use of goats worldwide, particularly in Asia, Africa, the Middle East, and Latin America (Smith and Sherman, 1994). Most of the goats kept in Zambia are of indigenous types and are mostly kept by the smallholder farmers. According to the socio-economic surveys carried out in the Gwembe valley by Lovelace *et al.*, (1993) it remains clear that goats are quite important to small-holder farmers. Goats are well integrated into the existing farming systems in Zambia and are a source of wide range of products including milk, meat, skin, and manure which may be readily converted into cash (Mwenya., 2001). Apart from the seasonal demand for goats, for religious rites and parties, goat meat is gaining general acceptance as a regular menu in homes and restaurants in Zambia (Mwenya., 2001). In some sectors of society, they serve as barter objects and are kept as assets used as gifts at funerals, weddings and as dowry (MACO, 2003).

2.4 The importance of indigenous goats in Zambia

The indigenous goats are an important resource and play vital socio-economic roles in the livelihood strategies of the poor farmers, especially those in rural and hard-to-reach areas in Zambia (Mwenya., 2001).The importance of these goats is due to their adaptability in many parts especially in marginal areas, which are unsuitable for cattle rearing for a number of reasons. Due to their adaptability, the indigenous goats are and will remain of perculiar use due to their trypanotolerance and high drought resistance (Ahmadu *et al*., 2002). The latter characteristic makes the role of indigenous goats crucial to the rural family survival (Lovelace *et al.*, 1993).The future of indigenous goats remains bright due to the realisation by policy makers that goat rearing should be promoted as part of the poverty alleviation programmes (Chisanga, 2000).

2.5 Skull biometry and its use in the study of domestic and wild animals.

Skull biometry which involves the analysis of data generated from the linear measurements of the skull of an animal using anatomical landmarks and mathematical and statistical methods is a useful tool in studying domestic and wild animal breeds and their morphometric characteristics (Thomason., 1991). The significance of skull biometry in the study of domestic breeds cannot be over emphasized as the shape and appearance of the head is important in determining the nature of an animal (Dyce *et al.*, 2002). Craniometrical studies are vital because the skull is considered to be the major element of the skeleton indicating taxonomic affiliation, and can give information on changes in animals arising from selection (Bruenner *et al.,* 2002). In addition, craniometric studies of domestic animals are commonly reported in scientific literature due to the fact that the comparative data is of value in osteoarcheology (Guintard and Fouché., 2008; Grigson., 1974).

The morphological and morphometrical studies of the skull (skull biometry) not only reflect contributions of genetic and environmental components to individual development and describe the genetic and ecophenotypic variation, but are also foundations of the clinical, surgical and stereotaxic practices (Chimimba *et al.,* 2010; Wehausen and Ramey, 2000). It enables the surgeon to visualize details of structures relevant to the case at hand (Dyce *et al.,* 1996). Similarly, the different foramina of the skull are of clinical importance in regional anaesthesia around the head (Hall *et al*., 2000).

Studies of skull morphometry and applied clinical anatomy of the skull have been performed on different species of wild animals (Zhu, 2012 ; Sarma, 2006; Onar *et al.*, 2005), farm animals (Pares *et al*., 2010; Jakubowski *et al*.,2008) and domestic animals (Baranowski, 2010; Ornar, 1999) and covered different stages of evolution and ontogenesis. Craniometric studies have been useful particularly in determination of sexual dimorphism (Onar *et al.,* 2001), basic anatomy (Olopade and Onwuka 2005a; Saber, 1990), evolution and adaptive studies (Evans and McGreery, 2006) and also proved to be important in the fields of morphophysiology of mastication and in regional anaesthesia of the head (Olopade and Onwuka, 2005b). Because of the reliability of craniometric studies, today's dog breeds are typically classified using the craniometric measurements and cranial indices such as cephalic and cranial indices into brachycephalic, mesocephalic and dolicocephalic breeds (Onar, 1999;Von Brehm *et al.,*1985). Zhu (2012) used the sample principles to classify the Tibetan Gazelle (*Procapra picticaudata)* skulls as dolicocephalic in nature.

2.6 Skull morphometric of the Zambian goats and other goats in general

Although many craniometrical studies have been performed on many animals both domestic and wild animals and goats in particular, there remains a profound dearth in the literature regarding skull morphometric and morphology in indigenous Zambian goats. Such studies are vital for understanding the spatial relationships of organs in this region (Olopade and Onwuka, 2005a), for the study of the interactions between hereditary aspects and the environment (Onar *et al.*, 1997), and for the study of sexual dimorphism (De Paiva and Segre, 2003). An important aspect of the craniofacial anatomy of any animal is the skull typology of the species. The only available literature is about the morphometric body measurements of the unspecified Zambian local goats contained in the thesis by Ahmadu (2001). Although Ahmadu (2001) incorporated some aspects of the head profile and horn characteristics of the goats in his study, a gap in skull biometry data does exist in Zambian goats. Craniometric studies have been reported in goats for example, the West African Dwarf (Olopade and Onwuka, 2005a, b; Olopade, 2003) and the Anglo Nubian breeds (Goat Skull, 2005), and the Red Sokoto breed (Olopade and Onwuka, 2007).

Osteometric studies of the skull of small ruminants have been extended to measurements of distances on maxillofacial and mandibular aspects that of the clinical anatomical landmarks useful for regional nerve blocks of the head region (Samuel *et al*., 2013). In goats, such studies have been reported in Bengal goat breed (Uddin *et al*., 2009), West African Dwarf goat (Olopade and Onwuka, 2005), the Markhoz dwarf goat (Goodarzi and Hosseini, 2013) and goats from the middle-belt region of Nigeria (Samuel *et al*., 2013). The studies are of great importance as they measure distances around landmarks and around the foraminae in the skull where major nerves that are important for clinical, surgical aspect and regional anaesthesia around the head emerges (Hall *et al*., 2000).

Studies covering morphometrical and morphological parameters have employed to establish data on the regional anatomy of the head of small ruminants (Sarma, 2006). Karimi *et al*., (2011) discussed the usage of morphologic and morphometric characteristics of skulls in several basic and clinical applications in Mehraban sheep in Western Iran. The regional anatomy of the Kagani goat from Jammu region in India has been studied based on its morphological and morphometrical parameters (Sarma, 2006). Morphological parameters have been investigated in Sahel goat skull describing bones of the skull and how they differ among the ecotypes of the Sahel goats in Nigeria (Shawulu *et al*., 2011).

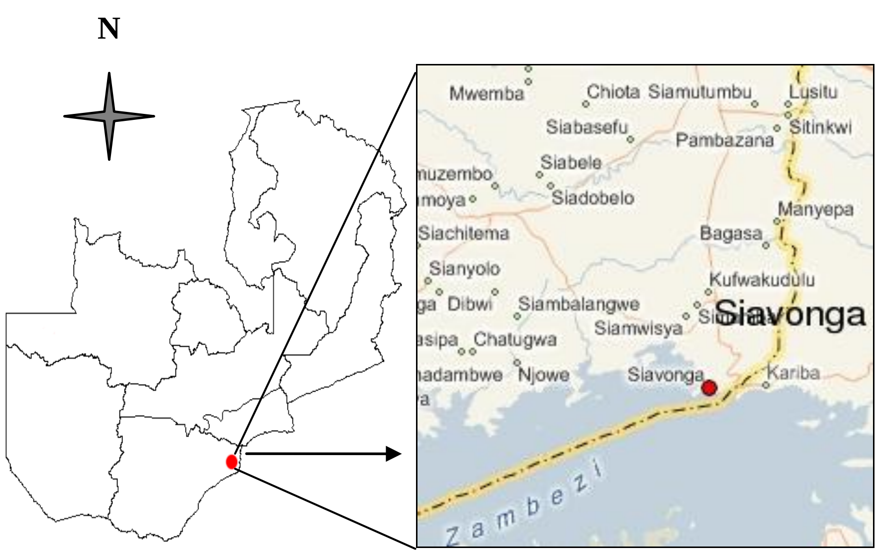
Based on the available information, it is clear that there is paucity of information regarding the biometrical and morphologic characteristics of the Gwembe Valley Dwarf goat skull. The present study therefore attempted to bridge the paucity of information on the regional anatomy of the head of the Gwembe Valley Dwarf goat with particular regard to biometrical data as it relates to craniometry and applied clinical anatomy, and the general skull morphology.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1. Study area

The study was carried out on indigenous goats from Siavonga district, located at 16.53° South latitude, 28.72° East longitude in the Southern province of Zambia (Siavonga Maps, 2011). This district is situated approximately 152.4 km south of Lusaka. The district has a mountainous landscape, lying about 950 meters above sea level. The climate is characterised by high temperatures of above 29^{o}C and annual rainfall of less than 800mm. The vegetation is predominantly Mopane woodlands and baobab trees (Lundu *et al.,* 2012). The district was chosen because besides being the highest goat producing district in the province, it has a higher population of the Gwembe Valley Dwarf goats compared to other districts with overall goat population estimated at 45,272 (DVLD, 2008) . Siavonga district is largely rural with subsistence farming and animal husbandry being the major activities. The animal husbandry is dominated by goat rearing mainly reared on free range management due to prevailing adverse climatic and environmental conditions (Lundu *et al.*, 2012).



(*Sourced from: Lundu et al., 2012*).

Figure 1: Map of Zambia showing the study area in Siavonga, Southern Province**.**

3.2 Study animals

The research focussed on the skull biometry of the Gwembe Valley Dwarf goat also known as the South East African dwarf goat aged 18 months and above. Thirty (30) fresh heads equally distributed between sexes from health animals without skeletal abnormalities were obtained following slaughter of the goats at an abattoir. The processed individual skull of the Gwembe Valley Dwarf goat was the study unit. The goat has adapted to hot and dry climatic conditions with low rainfall patterns. It has a small body size and a coat colour ranging from completely black, brown, black and white, grey to white and brown. The horns are of medium size and curved backwards (MACO, 2003: Chisanga and Mwenya, 1998). Figure 2 below shows the Gwembe Valley Dwarf goat.

(*Picture courtesy: Dr. A. Kataba)*

Figure 2 : Gwembe Valley Dwarf goats under restraint.

3.3 Study design

A cross sectional study design was used. This study design was employed due to its being best suited for investigation of permanent factors such as breed, sex and blood types in animals (Mann., 2003). Purposive sampling (Non-probability sampling) was used in this study based on Patton (1990). In this study, information rich cases were Gwembe Valley Dwarf goat aged 18 months and above. The fresh heads from slaughtered Gwembe Valley Dwarf goats were selected based on the known breed characteristics (Chisanga and Mwenya, 1998), good health and lack of skeletal abnormalities (Olopade and Onwuka, 2005b; Ahmadu, 2001).

3.3.1 Sampling period

The sampling and collection of fresh heads of Gwembe Valley Dwarf goat was done between November, 2012 and April, 2013.

3.3.2 Sample size determination

There has been no formula reported for sample size determination in craniometry and related studies in literature. In this study, a formula for determining a sample size of a single study group as postulated by Eng (2003) was used to calculate the sample size for our study. The following formula is designed to calculate a suitable sample size to estimate a mean:

$$\mathbf{n = \frac{4\sigma^2 (Z_{critical})^2}{D^2}}$$

Where **n** = the required sample size of a single study group, **σ** = the assumed standard deviation for the group. $\mathbf{Z_{critical}}$ = standard value of confidence level at 95% and **D** = expected total width of the expected confidence interval.

For this study,

σ = 2 (Standard deviation, maximum estimate from scientific literature reviewed from works done by Olopade and Onwuka (2005b)

$\mathbf{Z_{critical}}$ = 1.96 (Standard value of confidence level at 95%)

D = 1.5 (The assumed limits of the 95% confidence interval {Width of the interval will be no more than 0.75 above or 0.75 below the mean}).

Calculations: $\mathbf{n} = \frac{4(2)^2(1.96)^2}{(1.5)^2}$ = 27 individual skull samples will be required.

Therefore, as a way of rounding off to the nearest value, n = 30 individual skulls were sampled for this study.

3.3.3 Goat identification

The goats were identified at the local abattoir before slaughter based on the characteristics typical of Gwembe Valley Dwarf goats such as a small body size and a coat colour ranging from completely black, brown, black and white, grey to white and brown. The horns are of medium size and curved backwards (MACO, 2003: Chisanga and Mwenya, 1998). Further screening to establish the place of origin was done through harmonisation of the records obtained from the local abattoir 'manager' and the farmer or supplier.

3.4. Sample collection and preparation for analysis

3.4.1 Ethical consideration

All samples (fresh goat heads) were collected following slaughter of the Gwembe Valley Dwarf goats in the area designated locally for slaughter of goats whose meat was sold for consumption. And since the samples were collected from an abattoir, no ethical clearance was sought. This was in tandem with international guiding principles for Biomedical Research involving animals (Bankowski., 1985) developed by the Council for International Organizations of Medical Sciences (CIOMS).

3.4.2. Fresh heads sample collection

Thirty heads of goats identified as Gwembe Valley Dwarf goat aged 18 months and older were collected from the local abattoir (Chibolya market) where all types of goats

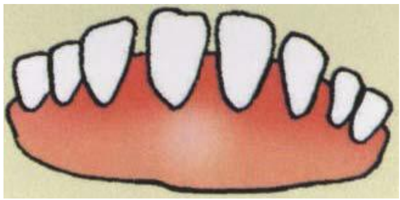
(Indigenous breeds) are sold and slaughtered from the Siavonga district and other parts of Zambia. The heads were selected based on apparent good health of animals noting characteristics such as lack of congenital deformities or any scars on the skulls (heads) from trauma (Olopade and Onwuka, 2005b). The sampling was stratified according to sex (15 males and 15 females). The age was estimated on the basis of the eruption of the permanent teeth as a guide (Vatta *et al*., 2006). Following slaughter, the heads were severed at the occipitoatlantal joint, and the heads were given numbers and placed in clean bags according to sex. As a final process in sampling, we wrote the numbers of each head in the bag on a piece of paper, the papers were placed in a hat and then drew out a few papers from the hat randomly. Only the drawn numbers of heads were purchased and later processed for morphometric analysis in the anatomy laboratory of the Samora Machel School of Veterinary Medicine at the University of Zambia.

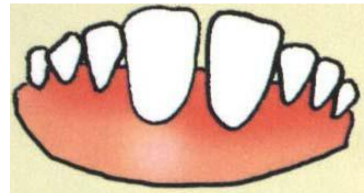
Table 1 : Age estimation in small ruminants

No. of permanent incisors	Sheep estimated age range	Goat estimated age range
0 Pair	Less than 1 year	Under 1 year
1 Pair	1-1½ years	1-2 years
2 Pairs	1½-2 years	2-3years
3 Pairs	2½-3years	3-4 years
4 Pairs	More than 3 years.	More than 4 years
Broken mouth	Aged	Aged

Permanent incisor teeth as a guide to age estimation in small ruminants (Vatta *et al*., 2006).

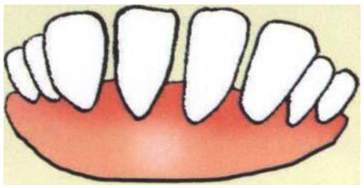
Below are the illustrations in figure 3 showing the goat dentition and estimated age for goats according to Vatta *et al*., (2006).

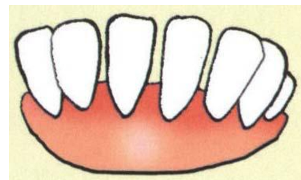




a: Milk teeth(Less than 1 year)

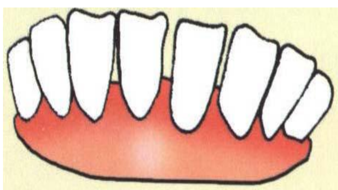
b: 2 permanent (central) teeth(1-2 years)

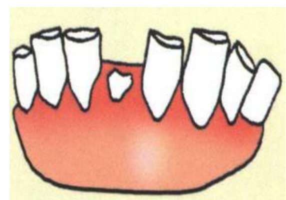




c: 4 permanent teeth(2-3 years)

d: 6 permanent teeth(3-4 years)





e: Full mouth – 8 permanent teeth(Above 4 years)

f: Broken mouth(Aged)

Figure 3 : Age estimation guide in goats based on dentition (a-f).

The guide was adopted from Vatta *et al*., 2006.

3.4.3 Maceration of the goat heads

The hot water maceration techniques as described by Simoens *et al.,* (1994) were used in this study. Briefly: the skin and most of the muscles were separated and eyes were enucleated using knives and scalpel blades from the fresh heads. The heads were heated to over 80ºC for 1 hour in solution of polycaboxylate and anionic surfactant (detergent, teepol) while monitoring the temperature using a thermometer as shown in Figure 4. The muscles of boiled heads were separated with the aid of forceps and scalpel in running water following boiling. The boiled heads were left to stand in the detergent water for 30 minutes after which the separation of remaining muscles and ligaments from the skull was done again and the skulls were left in 1% sodium hypochlorite solution for 24 hours. The skulls were then washed under running water and left in 1 %

sodium hypochlorite solution for 48 hours with the solution being changed twice after every 24 hours. From the hypochlorite solution, the final cleaning of the skulls was done under running tap water.

a. b.

Figure 4 : Monitoring boiling temperature (80°C) for heads (a). Clean skulls (b).

3.4.4 Drying of the skulls

The skulls were placed on trays and left in the sun for 7 days to dry.

3.4.5 Morphometrical measurements

Forty-three morphometrical measurements were obtained on all the thirty Gwembe Valley Dwarf goat skulls by means of measuring tape, ovinometer and a pair of Vernier callipers to the nearest 0.5 cm. The measurements were taken following the standards of Sarma (2006) and Von den Driesch (1976) except for variable 44 which was adopted from Zhu (2012). Von Driesch's numeration (Von den Driesch., 1976) was retained, except for variable 44 which was adopted from Zhu (2012) as shown in Figures 5, 6, 7 and 8.The measurements were taken systematically according to the six categories of skull parameters as below at the same time retaining the numbering corresponding to the standard used. As precaution to minimise measurement error, only the trained principal researcher took all the measurements (Von den Driesch., 1976).

A. Skull parameters (dorsal and basal surface)

1. Total length of the skull: the distance between points: akrokranion and prosthion.

2. Condylobasal length: aboral border of occipital condyles-prosthion.

3. Total length of the cranial basal: basion-prosthion.

4. Short skull length: basion-premolare.

8. Median frontal length: akrokranion-nasion.

9. Akrokranion-bregma.

10. Frontal length: bregma-nasion.

11. Upper neurocranium length: akrokranion-supraorbitale.

13. Akrokranion-infraorbitale of one side.

17. From the aboral border of one occipital condile to the infraorbitale of the same side.

26. Greatest mastoid breadth: otion-otion.

28. Greatest breadth at the bases of the paraoccipital processes.

31. Least breadth of parietal.

33. Greatest neurocranium breadth: euryon-euryon.

34. Greatest skull breadth: ectorbitale-ectorbitale.

35. Least breadth between the orbits: entorbitale-entorbitale.

B. Foramen magnum

27. Greatest breadth of the occipital condyles.

29. Greatest breadth of the foramen magnum.

30. Height of the foramen magnum: basion-opisthion.

C. Dental parameters

18. Dental length: postdentale-prosthion.

19. Oral palatal length: palatinoorale-prosthion.

20. Lateral length of the premaxilla: nasointermaxillare-prosthion.

21. Length of the maxillary tooth row.

22. Length of the upper molar row.

23. Length of the upper premolar row.

39. Greatest palatal breadth.

D. Orbital parameters

24. Greatest inner width of the orbit: ectorbitale-entorbitale.

25. Greatest inner height of the orbit.

E. Facial and nasal parameters

5. Premolare-prosthion.

7. Upper length of the viscerocranium: nasion-prosthion.

12. Facial length: supraorbitale-prosthion.

14. Greatest length of the lacrimal: most lateral point of the lacrimal-the most oral point of the lacrimo-maxillary suture.

15. Greatest length of the nasals: nasion-rhinion.

16. Entorbitale-prosthion.

36. Facial breadth: between facial tuberosities.

37. Greatest breadth across the nasals.

38. Greatest breadth across the premaxilla.

F. Horn parameters

32. Greatest breadth between the lateral borders of horn core base.

41. Greatest diameter of horn core base.

42. Least diameter of horn core base.

43. Length of the horn core on the front margin.

44. Distance between horn tips.

Below are figures showing the Gwembe Valley Dwarf goat skull measurements that were taken as outlined above.

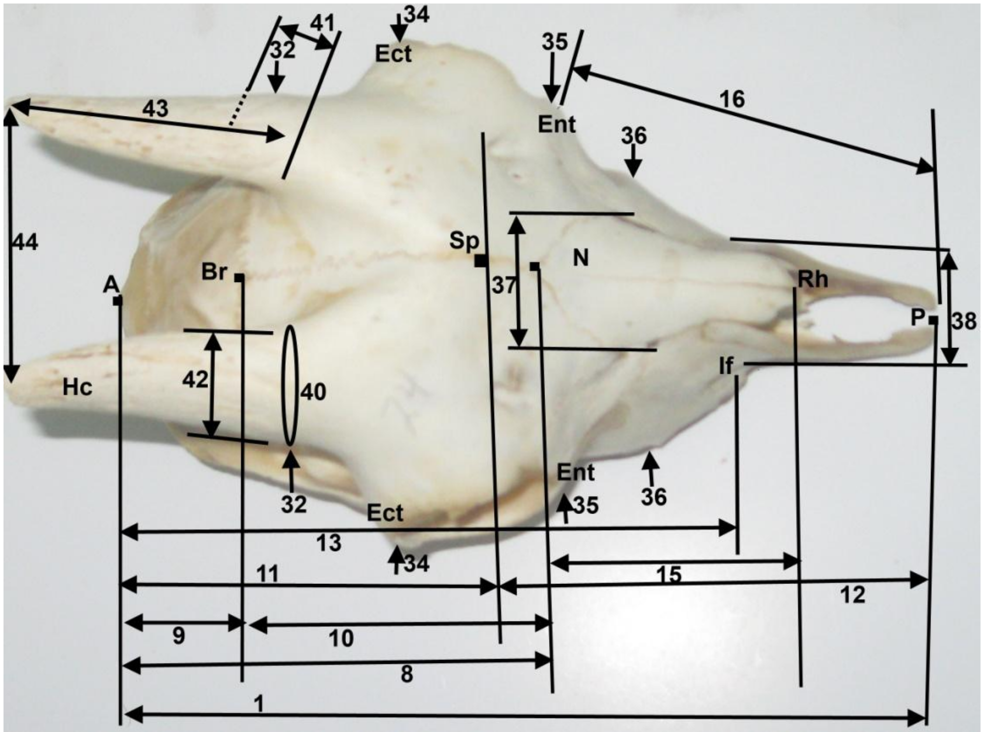


Figure 5 : Measurements of the skull of Gwembe Valley Dwarf (GVD) goat (Dorsal view)

A: Akrokranion, **Br**: Bregma, **Ect**: Ectorbitale, **Ent**: Entorbitale, **Hc**: Horncore, **If**: Infraorbitale, **N**: Nasion, **P**: Prosthion, **Rh**: Rhinion, **Sp**: Supraorbitale.

1: Total skull length, **8:** Median frontal length, **9:** Akrokranion-bregma, **10:** Frontal length, **11:** Upper neurocranium length, **12:** Facial Length, **13:** Akrokranion-infraorbitale of one side, **15:** Greatest length of the nasal bone, **16:** Short lateral facial length, **32:** Greatest breadth between the lateral borders of the horncore bases, **34:** Greatest skull breadth, **35:** Least breadth between the orbits, **36:** Facial breadth, **37:** Greatest breadth across the nasals, **38:** Greatest breadth across the premaxilla, **40:** Horncore basal circumference, **41:** Greatest diameter of horn core base, **42:** Least diameter of horn core base, **43:** Length of the horn core on the front margin, **44:** Distance between horn tips.

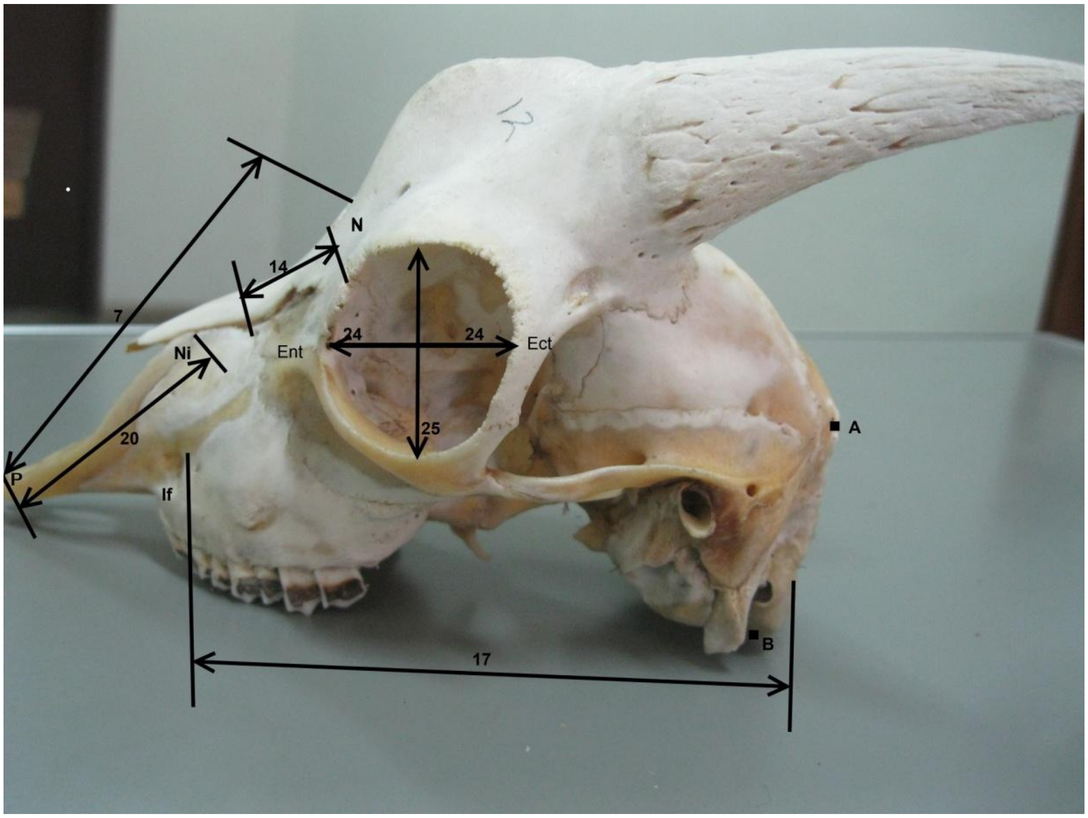


Figure 6: Measurements of the skull of the GVD goat (Lateral view).

A: Akrokranion, **B:** Basion, **Ect:** Ectorbitale, **Ent:** Entorbitale, **If:** Infraorbitale **N:** Nasion, **Ni:** Nasointermaxillare, **P:** Prosthion.

7: Viscerocranium length, **14:** Greatest length of the lacrimal bone, **17:** From the aboral border of one occipital condile to the infraorbitale (same side), **20:** Lateral length of the premaxilla, **24:** Greatest inner width of the orbit, **25:** Greatest inner height of the orbit.

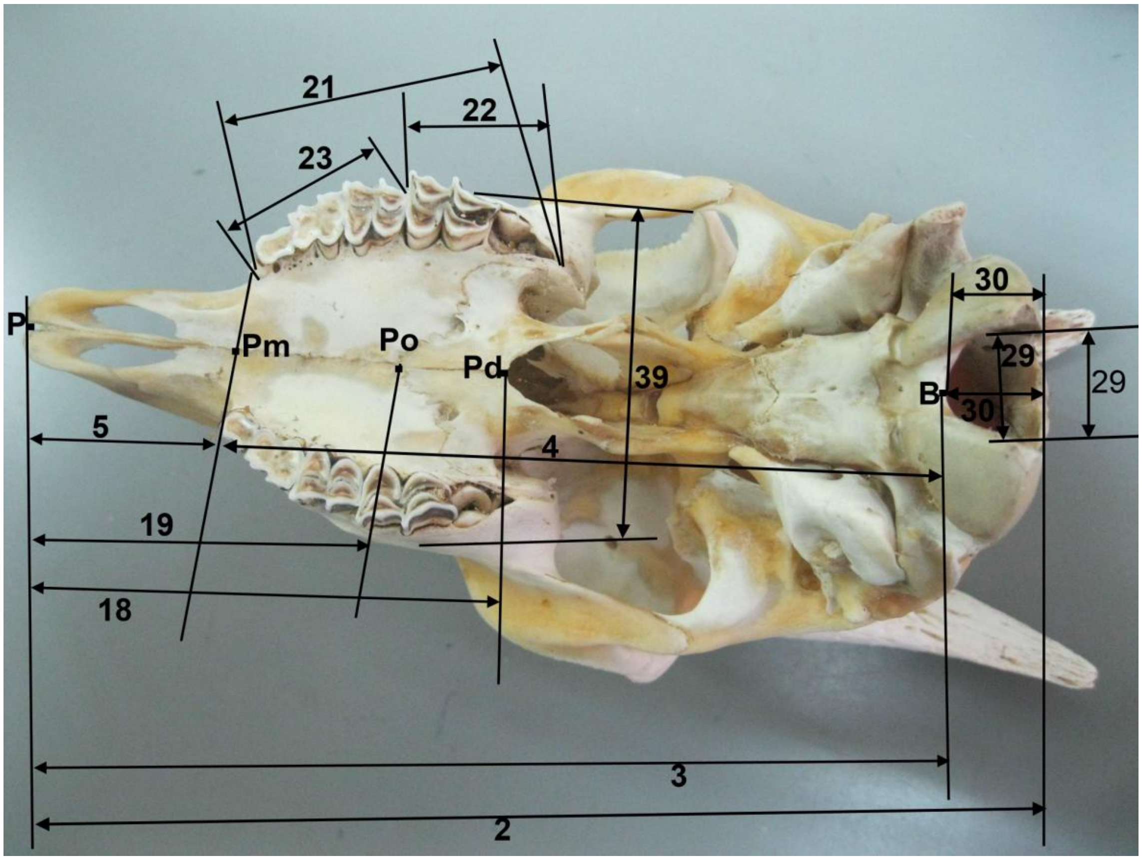


Figure 7: Measurements of the skull of the GVD goat (Basal view)

B: Basion, **P:** Prosthion, **Pd:** Postdentale, **Pm:** Premolare, **Po:** Palatinoorale

2: Condylobasal length, **3:** Total length of the cranial basal, **4:** Short skull length, **5:** Premolare to the prosthion, **18:** Dental length, **19:** Oral palatal length, **21:** Length of the premolar row, **22:** Length of the molar row, **23:** Length of the premolar row, **29:** Greatest breadth of the foramen magnum, **30:** Height of the foramen magnum, **39:** Greatest palatal breadth.

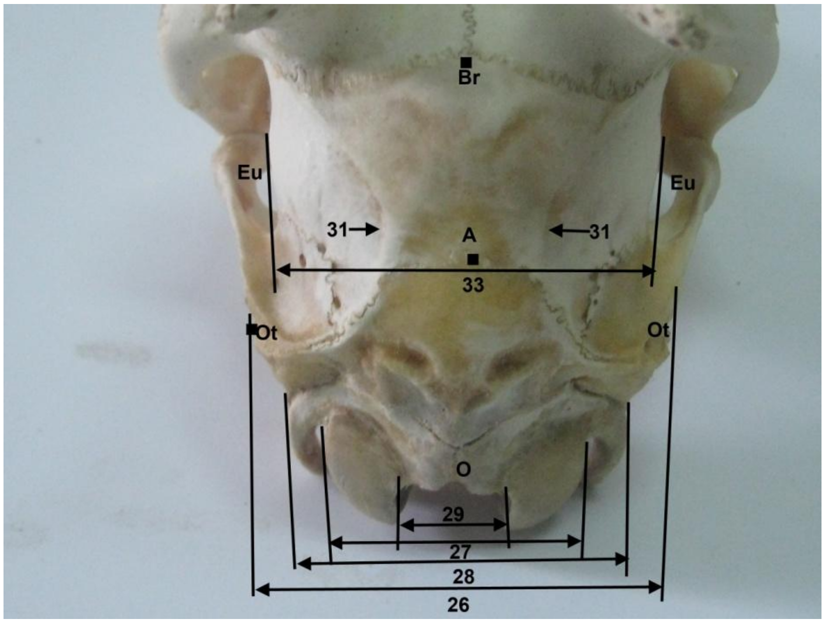


Figure 8: **Measurements of the skull of the GVD goat (Nuchal view)**

A: Akrokranion, **Br:** Bregma, **Eu:** Euryon, **O:** Occipitale, **Ot:** Otion

26: Greatest mastoid breadth, **27:** Greatest breadth of the occipital condyles, **28:** Greatest breadth at the bases of the paraoccipital processes, **29:** Greatest breadth of the foramen magnum, **31:** Least breadth of parietal, **33:** Greatest neurocranium breadth: euryon-euryon.

Von Driesch's numeration (1976) was used for all the measurements, except for variable 44 (figure 5) which was adopted from Zhu (2012).

3.4.6 Clinical anatomical measurements of skulls and mandibles

Measurements were taken on all the 30 skulls and mandibles for the clinical parameters. A total of 12 measurements were done in the upper jaw and mandibles using a measuring tape, ovinometer and a pair of Vernier callipers (Vernier®) of 0.02 mm).The measurements were taken following the standards of Uddin *et al*., (2009) and Olopade and Onwuka (2007). The parameters were measured for the upper and lower jawbones of the Gwembe Valley Dwarf goat skulls as described below and shown in Figures 9, 10, 11, and 12.

A. Facial tuberosity to infra-orbital canal: From the level of the most lateral bulging of the facial tuberosity to the mid level of the infra-orbital canal.

B. Infra-orbital canal to root of alveolar tooth: Measurement is taken vertically from the mid-level of the in infra-orbital canal to the root of the alveolar tooth.

C. Mandibular length: From the level of the cranial extremity of the alveolar root of the incisor to the level of the caudal border of the mandible.

D. Lateral alveolar root to mental foramen: Shortest distance from the mental foramen to the lateral extent of the alveolar root of lower incisor.

E. Mental foramen to the caudal mandibular border: From the level of the mental foramen to the extreme caudal border of the mandible.

F. Mandibular foramen to base of mandible*:* Vertical line from the ventral limit of the mandibular foramen to the base of the mandible.

G. Mandibular angle to below mandibular foramen: Length from the caudal most border of the mandible to the vertical line produced by description of measurement of mandibular foramen to base of the mandible.

H. Condyloid fossa to height of mandible: From the maximum height of mandible to the condyloid fossa.

I. Condyloid fossa to the base of the mandible: Vertical line from the condyloid fossa to the base of the mandible.

J. Maximum mandibular height: From the basal level of the mandible to the highest level of the coronoid process.

K. Caudal border of mandible to the level of mandibular foramen: Shortest distance from the mandibular foramen to the extreme caudal border of the angle of the mandible.

L. Mandibular foramen to mandibular angle: Length from the mandibular foramen to the angle of the mandible.

Figure 9: **Skull. Lateral view of the GVD goat (Anatomical landmark).**

A: Facial tuberosity to infraorbital canal. **B**: Infraorbital canal to root of alveolar tooth.

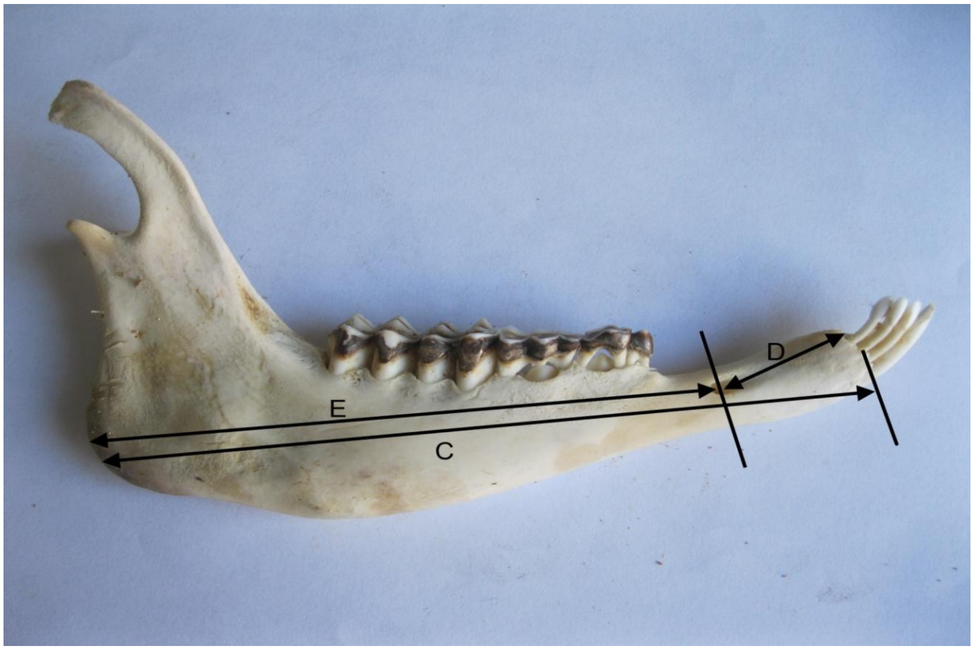


Figure 10 : Mandible .Lateral view of the GVD goat (Anatomical landmark).

C: Mandibular length, **D:** Lateral alveolar root to mental foramen. E: Mental foramen to mandibular border.

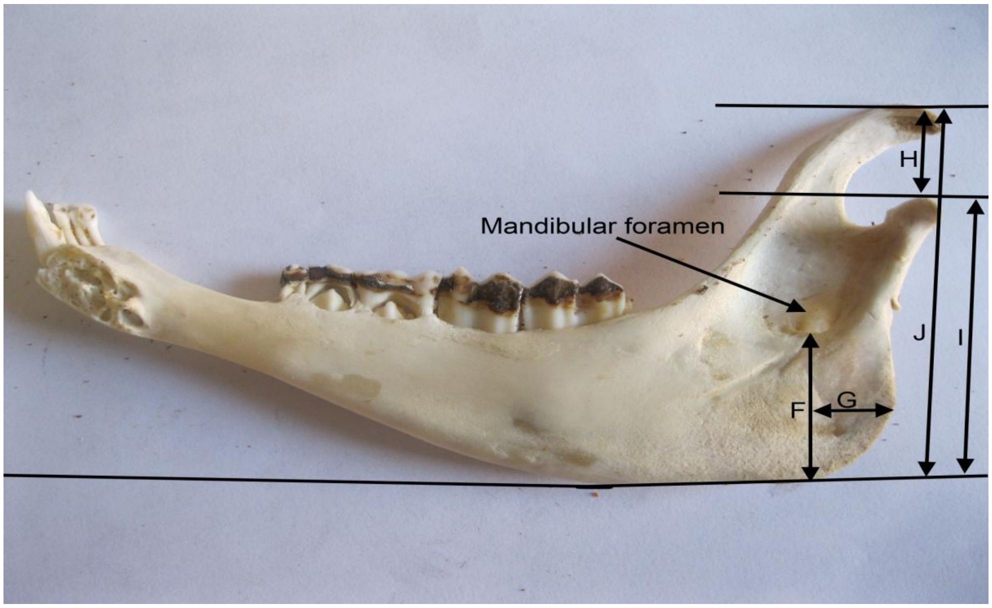


Figure 11 : Mandible. Medial view of the GVD goat (Anatomical landmark).

F: Mandibular foramen to base of mandible, **G**: Mandibular angle to below mandibular foramen, **H**: Condyloid fossa to height of mandible, **I**: Condyloid fossa to the base of the mandible, **J:** Maximum mandibular height.

Figure 12: **Mandible .Medial view of the GVD goat (Anatomical landmark).**

K: Caudal border of mandible to the level of mandibular foramen. **L:** Mandibular foramen to border of mandibular angle.

3.4.7 Morphological characteristics of Gwembe Valley Dwarf goat

The form (shape, size and position) of some bones of the thirty skulls of the Gwembe Valley Dwarf goats were studied and compared using the information of Olopade *et al*., (2006a), Dyce *et al*., (2002) and May (1970) as a guide.

3.5 Data Analysis

Data analysis in the current study was done under four (4) categories namely, morphometric (craniometric), sexual dimorphism in the head morphology, clinical anatomy aspects and the morphological examination. The data was entered and stored in an excel spread sheet and later imported to the softwares for analysis as described below for each category.

3.5.1 Morphometrical data and indices

Data was analysed using "Paleontological Statistics Software Package for Education and Data Analysis (PAST) developed by Hammer *et al.*, (2001) available at http://www.nhm.uio.no/norlex/past/download.html and some components were analyzed using Statistical Package for Social Scientists(SPSS) version 16. The descriptive statistics such as mean, the standard deviation, and coefficient of variations were calculated for each individual measurement obtained from the Gwembe Valley Dwarf goat skull for general description of the skull. The multivariate analysis using Principal Component Analysis (PCA) was done to isolate the variables that define variance on the craniometric data of the Gwembe Valley Dwarf goats. The Spearman's and Pearson's correlations were done to elucidate the relationship of the skull length and skull breadth with other variable and indices and the correlation indices between horn parameters were also obtained in order to know the harmony of the structure. Because some variables were not normally distributed Spearman's correlation was used (Anderson, 2001) with level of significance been declared at $p<0.05$.

For descriptive purposes, eleven indices or ratios were calculated according to Baranowski *et al*., (2009), Miller *et al*., (1964), Parés *et al*., (2010) and Sarma (2006) and recorded:

1) Skull/cephalic index: [Greatest skull breadth (34) / total length of the skull (1)] x 100.

2) Cranial index (neurocranium index): [greatest neurocranium breadth (var. 33)/ median frontal length (var. 8)] x 100.

3) Area of the foramen magnum: by using the formula ¼ bh, where b=breadth (var. 29) and h=height (var. 30) of the foramen magnum.

4) Foramen magnum index: [height of the foramen magnum (var. 30) / greatest breadth of the foramen magnum (var. 29)] x 100.

5) Orbital index: [orbital inner width (var. 24) / orbital inner height (var. 25)] x 100.

6) Orbital area: 27/7ab, where a and b are the halves of orbital inner width (var.24) and height (var. 25), respectively.

7) Facial index: [facial width (var. 36) / facial length (var. 12)] x 100.

8) Frontal index: [least breadth between the orbits (var. 35) / frontal length (var.10)] x 100.

9) Nasal index: [greatest breadth across the nasals (var. 37) / greatest length of the nasals (var. 15)] x 100.

10) Index I: [euryon-euryon (var. 33) / akrokranion-prosthion (var. 1)] x 100

11) Index II: [euryon-euryon (var. 33) / basion-prosthion (var. 3)] x 100

3.5.2 Comparative skull morphometrics of male and female goat

Main simple descriptive statistics (range, mean, standard deviation and coefficient of variation) were obtained, as well as the Shapiro-Wilk W to assess normality of distribution of data in both sexes for the 15 female and 15 male skulls of the Gwembe Valley Dwarf goat respectively. The non-parametric one-way (NPMANOVA) test (Non-Parametric MANOVA, also known as PERMANOVA) was applied, using the Mahalanobis distance (Anderson, 2001). The significance was computed by permutation of group membership, with 9,999 replicates. Given the large number of parameters, a selection of the most relevant parameters was ultimately made using a multivariate analysis of principal components (PCA). The principal components (PC) were extracted from the co-variance matrix. The eigenanalysis was carried out on the group means ("between-group", i.e. the items analyzed were the groups, not the specimens). The loadings within the individual eigenvectors for each PC were used to form contrasts in order to describe the skulls numerically. A one-way MANOVA (Multivariate Analysis Of Variance) tested whether male and female samples had the same mean for the most discriminant parameters. And since some of the parameters presented a non- normal distribution, in order to identify and measure the associations among the two sets of parameters, a Canonical Correspondence Analysis was done, according to Legendre and Legendre (1998) and the two-tailed non-parametric U Mann-Whitney was used to test whether the medians of samples were different.

3.5.3 Clinical anatomy data

Data was analysed using PAST- "Paleontological Statistics Software Package for Education and Data Analysis" (Hammer *et al.*, 2001).The mean and the standard deviation, were calculated for each individual measurement obtained from the Gwembe Valley Dwarf goat. The mean values with their respective standard deviations of the Gwembe Valley Dwarf goat were compared with the mean values obtained in the WAD goat by Olopade and Onwuka (2005a) and in Bengal goat by Uddin *et al*., (2009) and in the Markhoz dwarf goat by Goodarzi and Hosseini (2013) using an unpaired two-tailed student's t-test at $\alpha = 0.05$ or 95% level of significance. This should in theory only be used when measurements are normally distributed, but it does represent a 'robust' test, which is little affected by normality or variance (Simpson *et al*., 1960).

3.5.4 Morphological characteristics of the Gwembe Valley Dwarf goat

There was no statistical treatment done on the observations made on the Gwembe Valley Dwarf goat skull and mandible which were recorded and compared using descriptive terms with that of other goats and animals based on the information of May (1970); Dyce *et al*., (2002) and Olopade *et al*., (2006).

CHAPTER FOUR

4.0 RESULTS

The results from the study of the skull biometry of the Gwembe Valley Dwarf goat were categorised under four (4) categories namely, morphometric (craniometric), sexual dimorphism in the skull morphology, clinical anatomy aspects and the morphological examination as reported below.

4.1 Morphometric (Craniometric) measurements

The mean, standard deviation and the coefficient of variation (CV) of the Gwembe Valley Dwarf goat morphometry values were determined and appear in Table 2. The mean skull length for the Gwembe Valley Dwarf goat was found to be 15.02 ± 1.09 cm, with the skull breadth and the viscerocranium length of 8.14 ± 0.39 cm and 8.54. ± 0.64 cm, respectively. The condylobasal mean length was 14.52 ± 1.12 cm and the mean height of the foramen magnum was 1.62 ± 0.10 cm. The length of the horncore on front margin was found to be 5.43 ± 1.47 cm with a highest coefficient of variation of 26.99% .The Gwembe Valley Dwarf goat's greatest breadth of the occipital condyles measured 4.10 ± 0.14 cm with the lowest coefficient variation value of 3.38% compared to other variables.The other measurements with their respective coefficient of variations are as indicated in the Table 2.

Table 2 : Descriptive statistics for the Craniometrical (morphometric) measurements in cm (Skull, foramen magnum, dental and orbital).

VARIABLE	MEAN±SD	95% Confidence Interval for mean		CV (%)
		Lower bound	Upper bound	
A. SKULL PARAMETERS				
1. Total length of the skull	15.02±1.09	14.61	15.43	7.29
2. Condylobasal length	14.52±1.12	14.10	14.94	7.68
3. Total length of the cranial basal	12.8 ±0.80	12.50	13.10	6.18
4. Short skull length	8.63±0.85	8.31	8.94	9.18
8. Median frontal length	8.58±0.64	8.34	8.82	7.28
9. Akrokranion-bregma	4.96±0.22	4.88	5.04	4.46
10. Frontal length	5.95±0.36	5.82	6.08	5.98
11. Upper neurocranium length	9.02±0.56	8.81	9.22	6.16
13. Akrokranion-infraorbitale of one side	10.68±0.53	10.48	10.87	4.95
17. Distance between occipital condile to the infraorbitale	11.04±0.59	10.82	11.26	5.30
26. Greatest mastoid breadth	5.86±0.27	5.76	5.96	4.52
28.Greatest breadth at the bases of the paraoccipital processes	5.33±0.21	5.25	5.41	4.02
31. Least breadth of parietal	3.04±0.07	2.89	3.19	12.82
33. Greatest neurocranium breadth	5.85±0.23	5.76	5.94	3.97
34. Greatest skull breadth	8.14±0.39	7.99	8.29	4.83
35. Least breadth between the orbits	6.36±0.38	6.22	6.50	6.02
B. FORAMEN MAGNUM PARAMETERS				
27. Greatest breadth of the occipital condyles	4.10±0.14	4.05	4.15	3.38
29. Greatest breadth of the foramen magnum	1.83±0.12	1.78	1.88	6.62
30. Height of the foramen magnum	1.62±0.10	1.58	1.66	6.09
Area of the foramen magnum (cm^2)	0.74±0.08	0.71	0.77	11.05
C. DENTAL PARAMETERS				
18. Dental length	7.76±0.54	7.55	7.96	6.99
19. Oral palatal length	6.12±0.39	5.98	6.26	6.32
20. Lateral length of the premaxilla	5.53±0.42	5.37	5.67	7.56
21. Length of the maxillary tooth row	4.78±0.45	4.61	4.95	9.48
22. Length of the upper molar row	2.80±0.13	2.75	2.85	4.56
23. Length of the upper premolar row	2.05±0.43	1.89	2.21	20.99
39. Greatest palatal breadth	5.48±0.26	5.38	5.58	4.70
D. ORBITAL PARAMETERS				
24. Greatest inner width of the orbit	3.11±0.18	3.04	3.18	5.70
25. Greatest inner height of the orbit	3.15±0.13	3.10	3.20	4.23
Orbital area (cm^2)	7.69±0.51	7.50	7.88	6.64

Table 3 : Descriptive statistics for the Craniometrical (morphometric) measurements in cm (facial,nasal and horn parameters).

VARIABLE	MEAN±SD	95% Confidence Interval for mean		CV (%)
		Lower bound	Upper bound	
E. FACIAL AND NASAL PARAMETERS				
5. Premolare to the prosthion	4.00±0.30	3.89	4.11	7.49
7. Viscerocranium length	8.58±0.64	8.36	8.82	6.96
12.Facial Length	9.62±0.51	9.43	9.81	5.26
14. Greatest length of the lacrimal bone	2.58±0.30	2.47	2.69	11.58
15. Greatest length of the nasal bone	4.67±0.49	4.49	4.85	10.52
16. Short lateral facial length	8.86±0.66	8.61	9.10	7.41
36. Facial breadth	5.62±0.29	5.51	5.73	5.12
37. Greatest breadth across the nasals.	2.11±0.23	2.02	2.20	11.03
38. Greatest breadth across the premaxilla	2.21±0.17	2.15	2.27	7.95
F. HORN PARAMETERS				
32. Greatest breadth between the lateral borders of the horncore bases	6.59±0.40	6.44	6.74	6.10
40. Horncore basal circumference	7.29±1.68	6.66	7.92	23.08
41. Greatest diameter of horn core base	2.59±0.36	2.45	2.73	13.98
42. Least diameter of horn core base	2.00±0.04	1.91	2.09	11.60
43. Length of the horn core on the front margin	5.43±1.47	4.88	5.98	26.99
44. Distance between horn tips	6.46±1.00	6.09	6.83	15.43

4.1.2 Craniofacial Indices of the Gwembe Valley Dwarf goat

Craniofacial indices calculated from the craniometric variables for the Gwembe Valley Dwarf goat are as shown in Table 4 below.

Table 4 : Craniofacial Indices of the Gwembe Valley Dwarf goat, n=30

	MEAN	SD	CV(%)	MIN	MAX
1.Skull/cephalic index	54.36%	3.37	6.20	49.19	63.17
2.Cranial index	66.49%	5.43	8.17	57.14	77.92
3.Foramen magnum index	88.49%	5.61	6.34	76.15	101.04
4.Orbital index	99.10%	7.54	7.61	87.05	114.29
5.Facial index	58.5 %	3.46	5.91	51.54	66.69
6.Nasal index	45.61%	5.49	12.03	36.84	54.97
7. Frontal index	107.22%	8.59	8.01	96.45	135.30
8.Index I	39.07%	2.55	6.53	34.65	45.44
9.Index II	45.57%	3.06	6.71	39.72	51.59

4.1.3 Relationship of the skull length and breadth with other variables

The Gwembe Valley Dwarf goat skull length was negatively correlated both to the upper neurocranium length and the cephalic index .The skull length was positively correlated to the orbital index, the facial index, the basal length and the greatest neurocranium breadth. And the skull breadth was positively correlated with the facial index and no correlations with other variables and indices were observed as depicted in Table 5.The following criterion was used to evaluate correlation coefficients; only values of Spearman’s correlation coefficient (rho) with a p- value of less 0.05 ($p < 0.05$) significance level (two-tailed) were considered significant

Table 5 : Spearman's correlations (n=30)

Dependent variable/index	Skull length(rho)	p-value	Skull breadth(rho)	p-value
1. Cephalic index	-0.79*	< 0.001	0.07	0.479
2. Basal length	0.39*	0.015	0.33	0.071
3. Cranial index	0.14	0.457	-0.07	0.529
4. Orbital height	-0.19	0.223	-0.11	0.832
5. Orbital index	0.69*	< 0.001	0.23	0.086
6. Facial index	0.55*	0.008	0.49*	0.018
7. Frontal index	0.19	0.384	0.29	0.377
8. Upper neurocranium length	-0.43*	0.059	-0.10	0.656
9. Greatest neurocranium breadth	0.42*	0.007	0.11	0.349
10. Facial Length	0.18	0.521	0.23	0.326

*Correlation is significant at 0.05 level (2- tailed).

4.1.4 Principal Component Analysis of the Gwembe Valley Dwarf goat Skull

From the multivariate analysis of the 44 variables measured for each skull using the principal component analysis of the Gwembe Valley Dwarf goat, ten Principal Components (PC) with eigenvalues greater than 1 were isolated. PC 1 with component loadings between -0.132 to 0.239 accounted for 34.18% of the total variation. The PC 2 accounted for a total of 12.45%. The PC 3 accounted for a total of 9.28 % of the total variation (Table 6). Each variable was given a load, being the correlation coefficient reflecting the linkage of a variable with a given component. But no load for first three PCs was > 0.44 (Table 7). The cumulative variance of these components accounted for 84.71% with PC 1 and PC 10 contributing 34.18% and 2.54% respectively as indicated in Table 6. Table 7 shows the component loading matrix for the first three (3) principal components from the analysis. Each loading value shows the contribution of a given variable to a particular principal component. The skull variation in Gwembe Valley Dwarf goat was centred on the first ten (10).

Table 6 : Principal Component Analysis for the craniometric data of the Gwembe Valley Dwarf goat (n=30)

PC	Eigenvalue	% variance	% cumulative variance
1	**14.697***	**34.180**	**34.180**
2	**5.356***	**12.456**	**46.636**
3	**3.992***	**9.284**	**55.920**
4	**3.009***	**6.998**	**62.918**
5	**2.300***	**5.350**	**68.267**
6	**1.825***	**4.244**	**72.512**
7	**1.487***	**3.458**	**75.970**
8	**1.428***	**3.320**	**79.290**
9	**1.235***	**2.872**	**82.161**
10	**1.096***	**2.548**	**84.709**
11	0.940	2.186	86.896
12	0.848	1.972	88.868
13	0.773	1.798	90.666
14	0.659	1.534	92.200
15	0.527	1.226	93.426
16	0.445	1.034	94.460
17	0.413	0.960	95.420
18	0.391	0.910	96.329
19	0.313	0.728	97.057
20	0.293	0.681	97.738
21	0.223	0.518	98.256
22	0.194	0.451	98.708
23	0.159	0.369	99.077
24	0.144	0.334	99.411

* Principal Components (PC) with eigenvalues greater than 1.

.

Table 7 : Component loadings for the Principal components from PCA.

Variable	PC1	PC2	PC3
1	0.202	-0.081	0.262
2	0.214	0.054	0.216
3	0.189	-0.110	-0.169
4	0.119	-0.206	-0.209
5	0.190	-0.065	0.122
7	0.178	0.013	-0.206
8	0.025	-0.188	-0.109
9	0.097	-0.036	-0.018
10	0.124	0.173	0.188
11	0.036	0.236	-0.338
12	0.152	0.019	-0.291
13	0.192	0.102	0.126
14	0.204	-0.015	0.010
15	0.190	-0.031	-0.039
16	0.181	0.070	0.077
17	0.223	0.127	-0.013
18	0.239	-0.079	-0.028
19	0.231	-0.112	-0.029
20	0.210	-0.013	-0.014
21	0.174	-0.140	-0.160
22	0.037	-0.222	0.087
23	0.161	-0.103	-0.007
24	0.154	-0.034	0.316

PC: Principal component. Numbers under variables represent the same variables used under the Von Driesch (1976) numeration as in text.

4.1.5 Relationships among the horn core parameters

From the Pearson's correlations, it was observed that some horn parameters of the Gwembe Valley Dwarf goat were correlated. The greatest breadth between the lateral borders of the horn core bases (32) was correlated to the greatest (oro-aboral) diameter of the horn core base (41), the least (latero-medial) diameter of the horn core base (42) and to the distance between horn core tips (44). Similarly, the greatest (oro-aboral) diameter of the horn core base (41) was positively correlated to the least (latero-medial) diameter of the horn core base (42),the length of the horn core on front margin (43) and the distance between horn core tips (44). The least (latero-medial) diameter of the horn core base (42) was positively correlated to the length of the horn core on the front margin (43) and the distance between horn core tips (44). However, no such correlation was observed with the distance between horn core tips (44) with the other horn parameters. The following criterion was used to establish correlation; only values with $p < 0.05$ were considered significant as indicated in Table 8.

Table 8: **Pearson's correlation between horn parameters of Gwembe Valley Dwarf goat (n =30)**

VARIABLE	32	41	42	43	44
32		0.002	0.003	0.084	0.000
41	0.539*		0.009	0.006	0.001
42	0.525*	0.467*		0.098	0.013
43	0.321	0.487*	0.308*		0.003
44	0.735*	0.590*	0.450*	0.523*	

* Significant correlations ($p<0.05$)

Key to Table 8: **32** greatest breadth between the lateral borders of the horn core bases. **41**- Greatest (oro-aboral) diameter of the horn core base. **42**- Least (latero-medial) diameter of the horn core base. **43-** Length of the horn core on front margin. **44-** Distance between horn core tips.

4.2.0 Comparative skull morphometrics of the female and male goats

The main comparative descriptive statistics for linear measurements for the two sets of skull parameters for the male and female Gwembe Valley Dwarf goat skulls calculated are indicated in Annex 8.1.

The non-parametric one-way analysis of variance (NPMANOVA) that was applied using the Mahalanobis distance reflected no statistical differences between sexes (F=1.104, p=0.317) on the general skull parameters. However, the NPMANOVA test on the horn parameters showed statistical differences between sexes (F=4.752, p=0.006) in Gwembe Valley Dwarf goat skulls as shown in Table 9.

Table 9: Non-parametric one-way analysis of skull and horn parameters

Parameters	F- ratio	p-value
General skull parameters	1.104	0.318
Horn parameters	4.752	0.006*

*Test significant at $p < 0.05$.

From the Principal Component Analysis (PCA) of the two sets of data skulls, three Principal Components (PCs) had eigenvalues greater than 1 and these were PC1, PC2 and PC3 as shown in Table 9. PC1, explained 43% of variance with significant loadings coming from variables 40 (horn core basal circumference) and 43 (length of the horn core on the front margin) which were both related to the horn parameters as shown in Annex 8.2**.** PC2 explained 23% variance with significant loading coming from variable 40 (horncore basal circumference) and PC3 explained 9% of the variance with significant loading coming from variable 4 (Short skull length) as shown in Annex 8.2.

Table 10: Principal Components in sexual dimorphism investigation

PC	Eigenvalue	% variance	Total explained
1	6.486	43.042	43.042
2	3.422	22.705	65.747
3	1.369	9.085	74.832
4	0.925	6.141	80.973
5	0.691	4.586	85.559
6	0.390	2.589	88.148

The first three principal components shown in Table 10 explained the 75% of the total observed variance. Highest values for each principal component appear in bold as indicated in Annex 8.2 under component loadings.

For these horn parameters the, NPMANOVA test did reflect statistical differences between sexes (F=4.752, p=0.006).

The Canonical Correspondence Analysis (CCA) for horn parameters, showed that the horn parameters had a strong influence on the skull differences between male and female Gwembe Valley Dwarf goat and specifically parameters 43 (1.23905, Can1) and 40 (-0.93511, Can1) as shown in Figure 13 below.

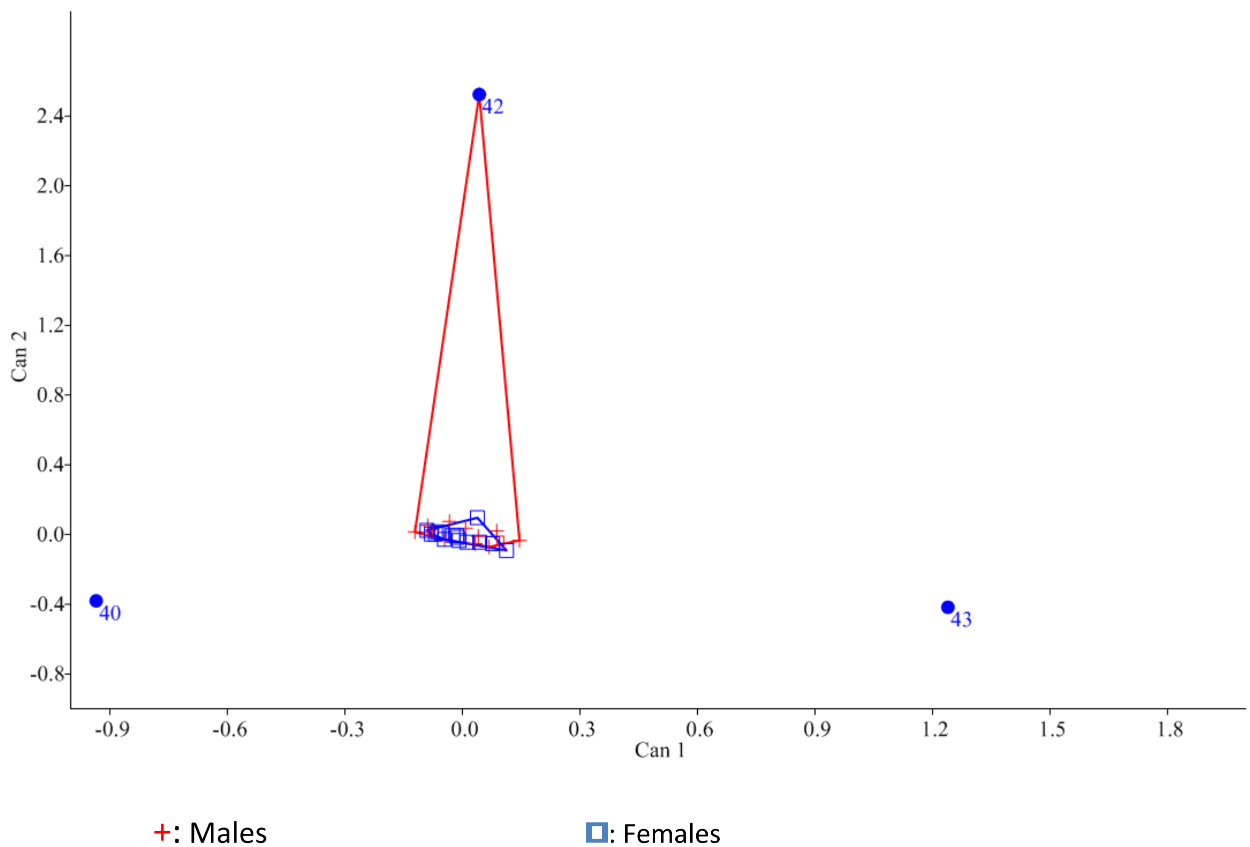
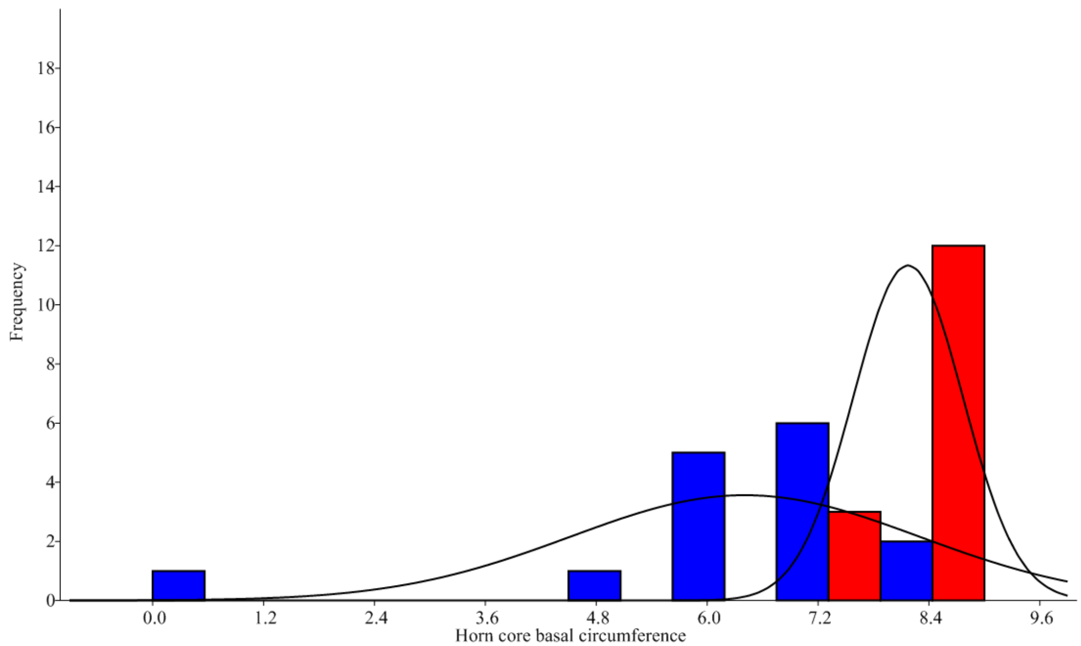


Figure 13 : Canonical Analysis for horn parameters

The blue squares and red crosses show the position of individual skulls according to the horn conformation (blue squares for males, red crosses for females, respectively). The numbers with dots show the analyzed horn parameters (40: Horncore basal circumference, 42: Least (latero-medial) diameter of the horncore base, 43: Length of the horncore on the front margin).

The Mann Whitney test on the female and male goat skulls for horncore basal circumference parameter was statistically different between sexes ($U=20.5$, $p<0.001$). These differences graphically as illustrated in Figure 14**.**



Blue bars: Females Red bars: Males

Figure 14 : Illustration on the horn parameter differences between male and females goat skulls of the Gwembe Valley Dwarf goat.

4.3 Clinical anatomy aspects of the Gwembe Valley Dwarf goat

This section contains the results obtained from measurements taken on all the thirty skulls and mandibles for the clinical parameters. The results were recorded in two parts; the first part had the summarised data in mean with standard deviation. The second part showed the results of comparative statistical analysis between the Gwembe Valley Dwarf goat skull regional mean measurements and other dwarf goat measurements.

4.3.1 Applied clinical anatomy of the upper jaw and mandible

This part of the study involved the measurements of some clinically important landmarks for possible use in regional anesthesia in the maxillary and mandibular regions of heads of the thirty Gwembe Valley Dwarf goats. The distance from the facial tuberosity to the infraorbital canal and from the latter to the root of the alveolar tooth directly ventral to it were 2.06 ± 0.14 cm and 1.13 ± 0.11 cm, respectively as shown in Table 11. The mandible of the Gwembe Valley Dwarf goat was found to have a length of 11.24 ± 0.52 cm and the height of 6.64 ± 0.44 cm. The mandibular angle to the vertical line below mandibular foramen was 1.21 ± 0.08, while the distance from the mandibular foramen to the base of the mandible was 2.35 ± 0.26 cm. The distance from the lateral alveolar root to the mental foramen was 1.58 ± 0.19 cm and that of the caudal border of the mandible to the mental foramen was 9.26 ± 0.49cm. The other aspects of the mandible were the distance of condyloid fossa to height of mandible which measured 1.43 ± 0.22 cm, the condyloid fossa to the base of the mandible which was 4.07 ± 0.37 cm, the caudal border of mandible to the level of mandibular foramen was 1.10 ± 0.07cm and the distance from the mandibular foramen to mandibular angle was 2.18 ± 0.19 cm as shown in Table 11.

Table 11: The Clinical measurements of the upper jaw and mandible (n = 30)

Variable	Mean ± SD
A. Facial tuberosity to infra-orbital canal:	2.06 ± 0.14
B. Infra-orbital canal to root of alveolar tooth:	1.13 ± 0.11
C. Mandibular length:	11.24 ± 0.52
D. Lateral alveolar root to mental foramen:	1.58 ± 0.19
E. Mental foramen to the caudal mandibular border:	9.26 ± 0.49
F. Mandibular foramen to base of mandible:	2.35 ± 0.26
G. Mandibular angle to below mandibular foramen	1.21 ± 0.08
H. Condyloid fossa to height of mandible	1.43 ± 0.22
I. Condyloid fossa to the base of the mandible	4.07 ± 0.37
J. Maximum mandibular height	6.64 ± 0.44
K. Caudal border to the level of mandibular foramen	1.10 ± 0.07
L. Mandibular foramen to mandibular angle	2.18 ± 0.19

4.3.2 Comparison of the applied clinical anatomy data of the Gwembe Valley Dwarf goat with other dwarf goat breeds.

The clinical mean values of clinical applied measurements of the Gwembe Valley Dwarf goat were compared with West African Dwarf (WAD) goat other dwarf goat breeds reported in literature as in Table 12**.**

Table 12: Comparison of the Gwembe Valley with the WAD and Markhoz dwarf goats

Parameter	Gwembe Valley Dwarf	WAD	P-value	Markhoz	P-value
A. Facial tuberosity to infra-orbital canal	2.06±0.14[b*]	--	--	1.81±0.06	< 0.0001
B. Infra-orbital canal to root of alveolar tooth	1.13±0.11[a*b*]	1.3-1.6	0.0012	1.7±0.08	< 0.0001
C. Mandibular length:	11.24±0.52	12.0±1.89	0.0380	13.37±0.67	< 0.0001
D. Lateral alveolar root to mental foramen	1.58±0.19	1.56±0.22	0.7077	1.58±0.11	1.0000
E. Mental foramen to the caudal mandibular border	9.26±0.49[a*b*]	9.96±1.67	0.0316	11.42±0.42	< 0.0001
F. Mandibular foramen to base of mandible:	2.35±0.26[a*b*]	2.58±0.34	0.0047	3.43±0.25	< 0.0001
G. Mandibular angle to below mandibular foramen:	1.21±0.08[a*b*]	1.57±0.44	< 0.0001	1.04±0.14	< 0.0001
H. Condyloid fossa to height of mandible	1.43±0.22[a*b*]	2.21±0.37	< 0.0001	2.45±0.15	< 0.0001
I. Condyloid fossa to the base of the mandible.	4.07±0.37[a*b*]	2.68±0.45	< 0.0001	5.87±0.44	< 0.0001
J. Maximum mandibular height:	6.64±0.44[b*]	6.9±1.09	0.3005	8.94±0.43	< 0.0001
K. Caudal border of mandible to mandibular foramen.	1.10±0.07[b*]	--	--	1.19±0.17	0.0266
L. Mandibular foramen to mandibular angle:	2.18±0.19[b*]	--	--	2.74±0.17	< 0.0001

a or* b* *significant difference between the Gwembe Valley Dwarf goat and WAD goat and Markhoz goat respectively at p<0.05 (p < 0.05, two-tailed at 95% significance level)*

a*b* *significance difference between the Gwembe valley dwarf goat and both the WAD and Markoz goat at p <0.05.*

4.4 Gross morphology of the Gwembe Valley Dwarf goat

The skulls and mandibles of all the thirty Gwembe Valley Dwarf goats were all grossly examined individually and the following were the observed features:

A. Frontal surface: This surface included the frontal, parietal, nasal and incisive bones as shown in Figure 15. The frontal bone comprised the largest part of the frontal surface, though it never extended up to the caudal extent of the skull. The frontal eminence was present on the midline, at the middle of the frontals. Caudolaterally, the eminence continued into the cornual process (Figure 15). The supraorbital foraminae were seen piercing the frontal bone each lying at the dorsolateral aspect and were located equidistant from the interfrontal suture, approximately 2cm away from the dorsal rim of the bony orbit. Notable was the presence of accessory supraorbital foraminae in some skulls depicting variation within the specie (Figure 15). The fronto-nasal suture appeared serrated and “V” shaped. The maximum width of the frontal surface was noticed at the level of the dorso-caudal margin of the orbits. The frontal bone eminence appeared distinctly in males and females skulls on the frontal surface rostro-caudally. Female skulls had a slightly straight frontal plain while the longitudinal convexity of the frontal bone was accentuated between the horns males (Figure 16).

The nasal bone were convex at the dorsal surface and broader proximal to the fronto-nasal suture. Rostrally, the nasal bones tapered to a point and appeared notched (Figure 15). The internasal suture was straight. The nasal bones were separated from the incisive, maxillary and lacrimal bones by intervening sutures (Figure 15).

The incisive bones made contact with the nasal bone caudodorsally and ventrally appeared fused with the maxilla bones. The rostral end of the incisive bone was blunt, with two long and narrow palatine fissures (Figure 15).

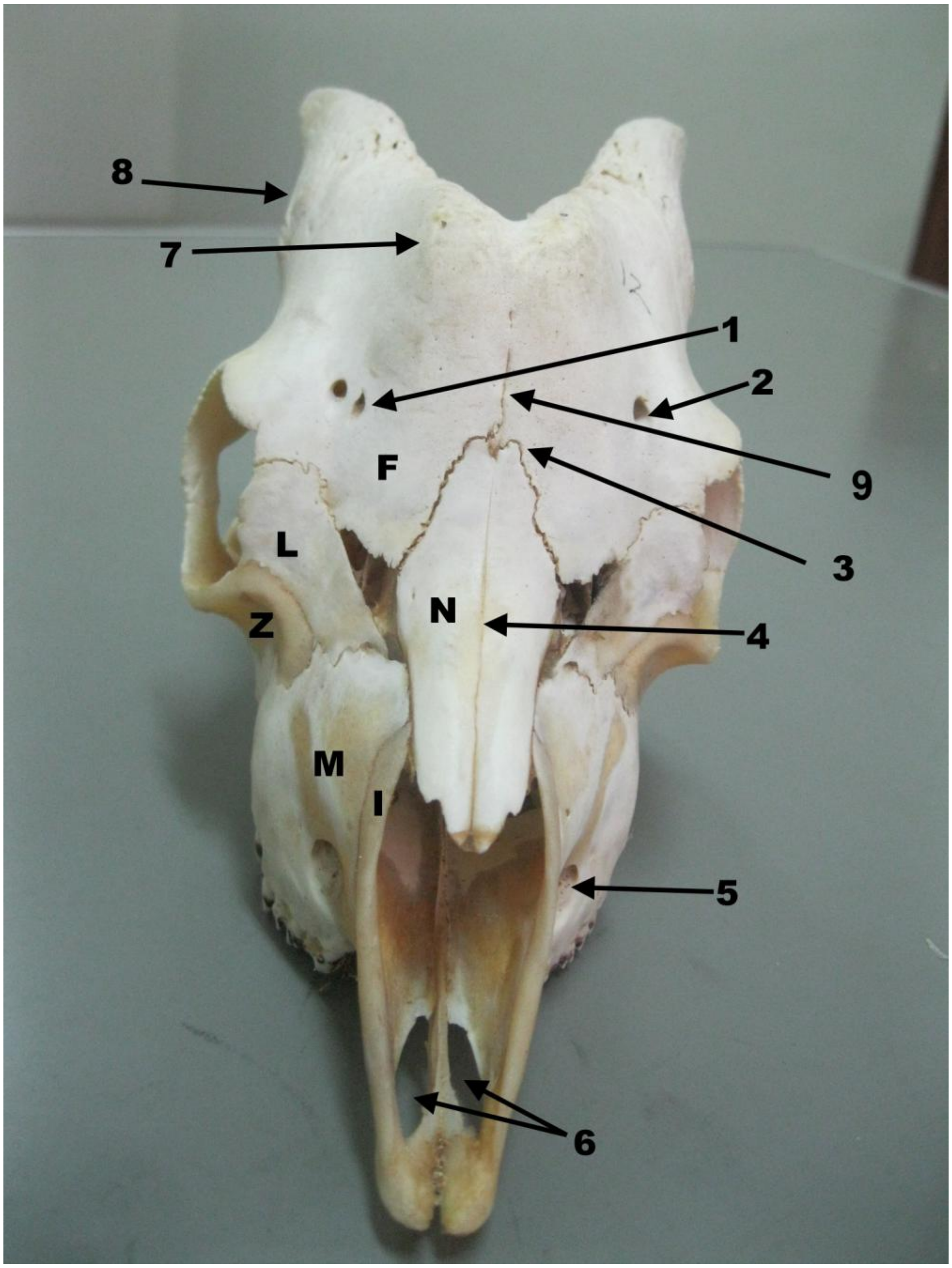


Figure 15: Skull morphology. Frontal/rostral view.

1. Accessory supraorbital foramen. **2.** Supraorbital foramen **3.** Fronto-nasal suture **4**.Internasal suture 5**.** Infraorbital foramen. **6.** Palatine fissure**. 7.** Frontal eminence**. 8.** Base of the cornual process **9**.Interfrontal suture**. Bones. I:** Incissive **F:** Frontal. **L:** Lacrimal **M:** Maxilla **N:** Nasal **Z:** Zygomatic.

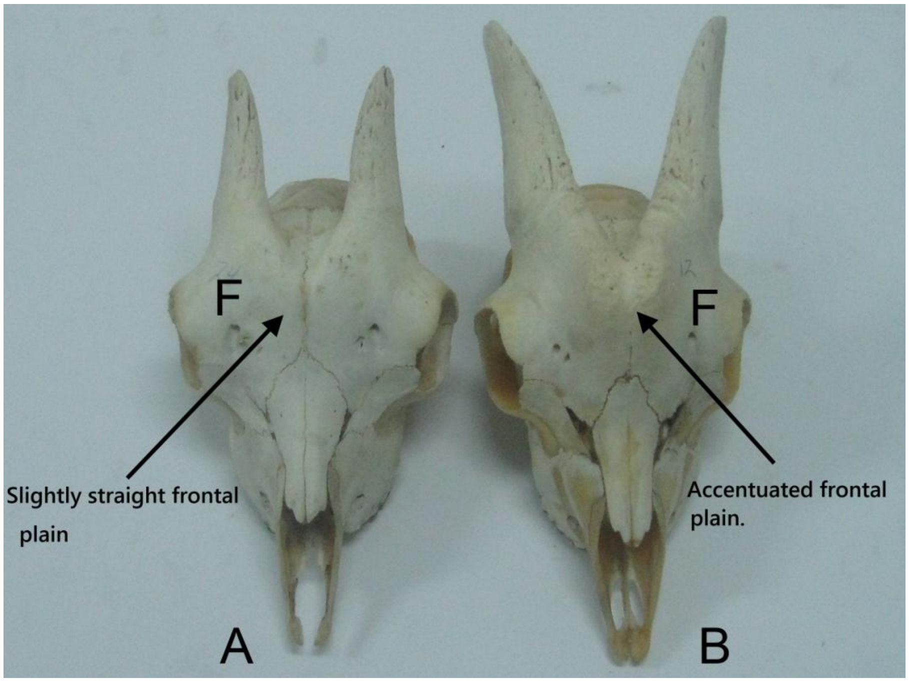


Figure 16 : **Skull morphology of the Gwembe Valley Dwarf goat. Frontal/rostral view**.

The frontal bone differences observed in Female **(A)** and Male **(B)** skulls of the Gwembe Valley Dwarf goat. **F:** Frontal bone. The male skull with a more accentuated frontal plain of the frontal bone than the female skull

B. Lateral surface: The lateral surface was composed of the temporal, the zygomatic, lacrimal and the maxilla bones. The temporal crest ended into a blunt tubercle caudo-lateral to the external auditory meatus (Figure 17). In this goat breed, the temporal fossa was extensive but shallow. The temporal bone consisted of the distinct squamous, tympanic and petro-mastoid parts. The squamous part resembled that of the ox but had a notch through which the external auditory meatus protruded. The root of the zygomatic process was perforated by a foramen which opened ventrally behind the postglenoid process in front of the chief external opening of the temporal canal. The tympanic part included the external auditory meatus, the tympanic bulla and the muscular process. The facial tuberosity was placed at the junction of the 3rd and 4th cheek teeth (upper) premolar. The infraorbital foramina were single on either side, placed on a depression (Figure 17). The orbital rims were complete, oval and the caudo-dorsal end of the rims was serrated. The basisphenoid bone had a sharp median ridge on its body. The frontal bones made the maximum contribution to the bony orbit, followed by the zygomatic and lacrimal bones, respectively. The orbital surface of the lacrimal bone was smooth and marked off from the facial surface by a dentated orbito-facial crest. A shallow fossa leading to the lacrimal canal was observed just behind the crest. The foramen ovale was located in the caudal part of the pterygoid bone (Figure 17).

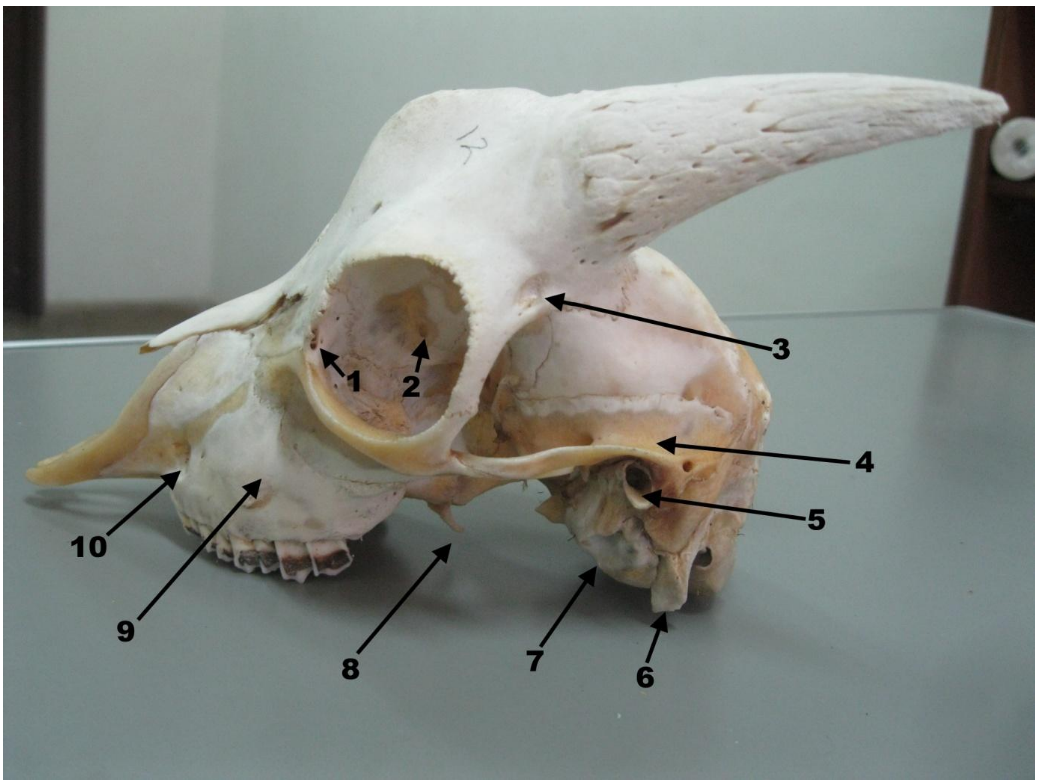


Figure 17 : **Skull morphology of the Gwembe Valley Dwarf goat. Lateral view.**

1. Lacrimal foramen **2.** Optic foramen **3**. Caudofrontal depression **4.** Temporal crest of the temporal bone. **5**. External acoustic meatus **6**. Paracondylar (Jugular) process **7**. Tympanic bulla **8**. Hamulus of the pterygoid bone **9**. Facial tuberosity **10**. Infraorbital foramen.

C. Basal surface: This surface exclusive of the mandible consisted of the cranial, choanal and palatine regions. The occipital condyles were limited in front by the transverse ridges. The condyloid fossae contained two foramina, the hypoglossal below and in front and the condyloid above and behind. The basilar part of the occipital bone was straight, and bound rostro-caudally by two pairs of muscular tubercles, with the rostral tubercles being larger (Figure 18). The median occipital crest was well developed. The occipital condyles met ventrally forming a “U” shaped intercondyloid cleft. The paracondylar (jugular) processes were curved latero-ventrally and tapered to a point. The tympanic bullae were small and compressed laterally. The tympanic bullae were in close apposition with the paracondylar processes caudally and on their rostral surface arose the short and pointed muscular process (Figure 18). The pterygoid bone was very broad above and narrow below where it ended in a sharp-pointed hamulus (Figure 18). The external acoustic process was directed almost straight outward. A curved plate extended ventrally from it and joined the bulla ossea medially, completing the deep concavity which receives the articular angle of the hyoid bone (Figure 18). The palatine portion was “U” shaped with a straight and smooth median palatine suture. The transverse palatine suture was “V” shaped and serrated, lying over the major palatine foramen. The dorsal border of the palatine bone was perforated by a sphenopalatine foramen (not shown in Figure 18 due to a difficult angle during the capturing of the photograph)**.** A well developed and prominent interalveolar margin was observed (Figure 18).

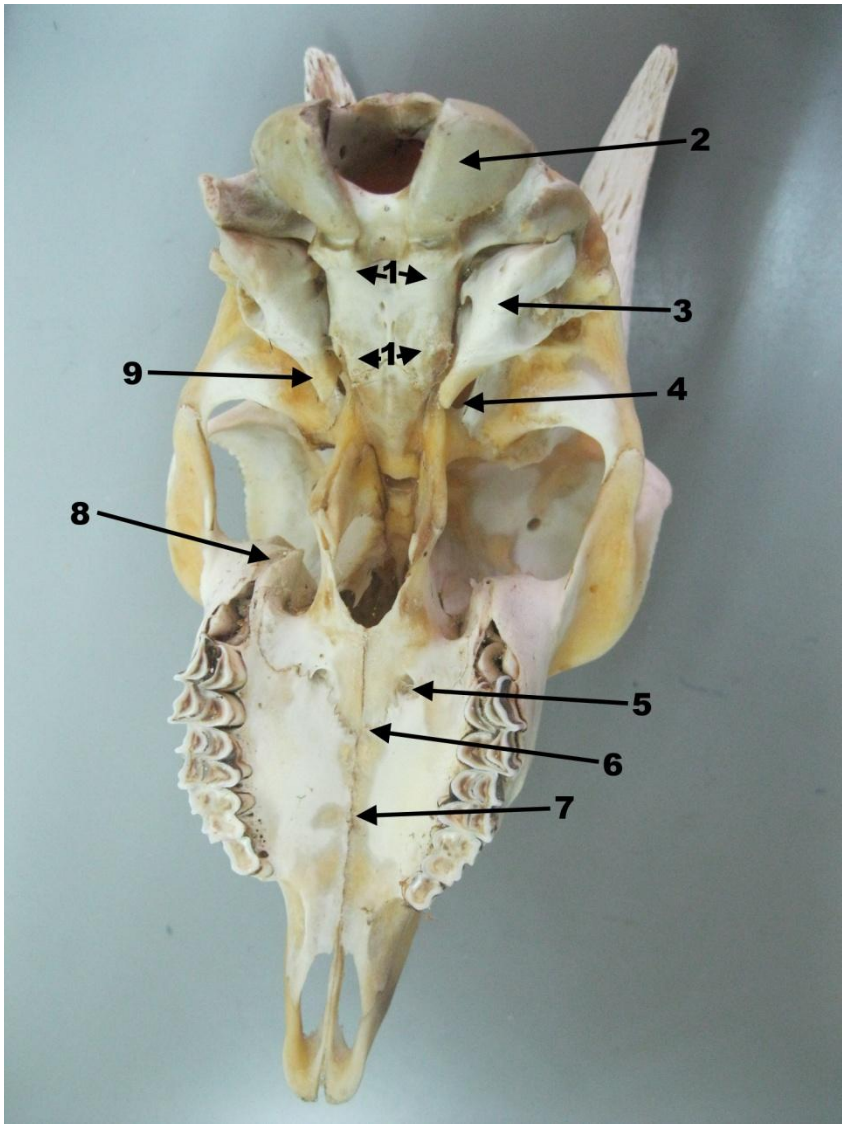


Figure 18: Skull morphology of the Gwembe Valley Dwarf goat. Basal view.

1. Muscular tubercle **2.** Occipital condyle **3**. Tympanic bulla **4**. Oval foramen **5.** Major palatine foramen **6**. Transverse palatine suture **7**. Median palatine suture**. 8.** Lacrimal bulla**. 9**. Muscular process.

D. The Caudo-dorsal and Nuchal surface: This was composed of the occipital, interparietal, parietal, frontal bone and the squamous part of the temporal bones. The occipital bone formed the entire Nuchal surface. This view was defined by two prominences, rostrally the frontal eminence and the external occipital protuberance. The frontal eminence was generally prominent and very prominent in males. From the frontal prominences arose at their extremities the cornual processes. These cornual processes were directed backwards characteristic of the Gwembe Valley Dwarf goat which has short horns directed caudally. At the base of the cornual process latero-ventrally and at the end of the temporal bone was a depression termed the caudofrontal depression (Olopade, *et al.*, 2006a) as shown in Figure 17.The external occipital protuberance was located on the external lamina of the squamous occipital bone and was sharp and pointed. Ventrally, the median occipital crest extended towards the foramen magnum. The occipital condyles were further apart and the articular surfaces were clearly divided into upper and lower parts. The mastoid foramen was at the junction of the occipital and temporal bones and it appeared small as shown in Figure 19.

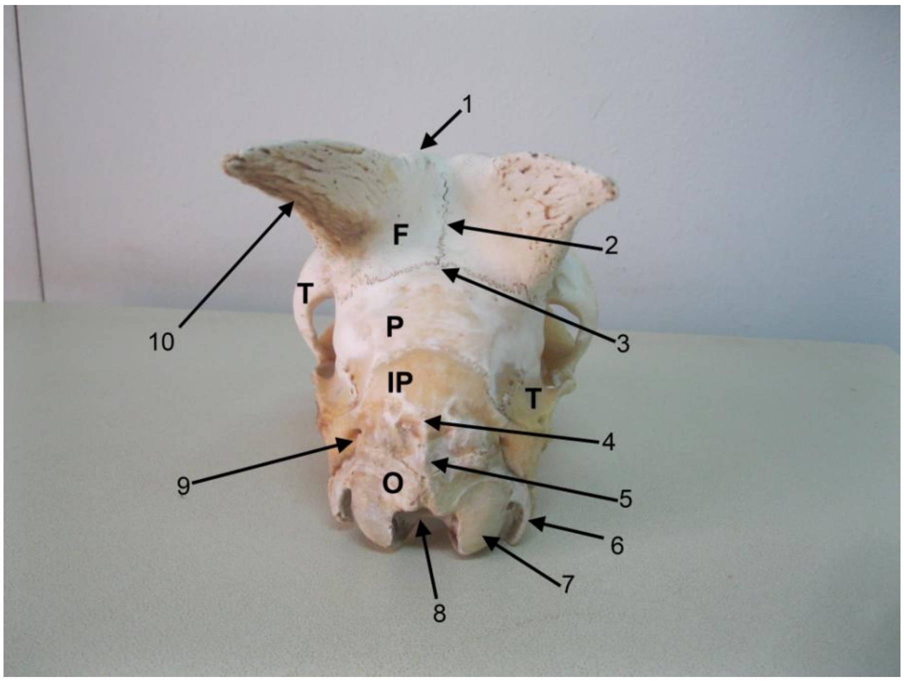


Figure 19 : **Skull morphology of the Gwembe Valley Dwarf goat. Caudo-dorsal/Nuchal surface.**

1: Frontal eminence. **2**: Interfrontal suture **3**: Fronto-parietal suture **4**: External occipital protuberance. **5:** Median occipital crest **6:** Paracondylar (Jugular) process **7:** Occipital condyle **8:** Foramen magnum. **9:** Mastoid foramen **10**: Cornual process. **Bones**: **F**: Frontal **IP**: Interparietal **O**: Occipital **P:** Parietal **T**: Temporal

CHAPTER FIVE

5.0 DISCUSSION

To our knowledge and according to available literature, this is the first study in Zambia that has documented the morphometric (craniometric), the sexual dimorphism in the skull morphology, the clinical or applied anatomy of the mandibular and maxillofacial regions measurements as well as the morphological makeup of the skull of the Gwembe Valley Dwarf goat. Due to lack of information in the areas mentioned above on Zambian goats, the results obtained in this study as shown in the result section forms the baseline data for the Gwembe Valley Dwarf goat skull. It is envisaged that this baseline data will be useful for future studies in the C*aprinae* subfamily and other species of domestic animals in Zambia. The implications and applicability of the results are discussed hereunder.

5.1. Morphometry of the Gwembe Valley Dwarf goat skull

The mean total skull length of the Gwembe Valley Dwarf goat was found to be 15.02 ± 1.09 cm. This suggests that the total skull length of the Gwembe Valley Dwarf goat is shorter than the West African Dwarf (WAD) goat whose total length reported to be 16.99 ± 1.59 cm (Olopade and Onwuka, 2005b). The condylobasal length in the present study was 14.52 ± 1.12 cm and it was shorter than the equivalent in the Red Sokoto goat and Anglo-Nubian goat breeds which were 20.2 cm and 21.5 cm, respectively (Olopade and Onwuka, 2008; Goat skull, 2005). The skull index of the Gwembe Valley Dwarf goat was 54.36 ± 3.37% and was higher than 51.36 ± 0.69 % and 50.42 ± 0.78 % of the Morkaman and Tuj sheep, respectively (Özcan *et al*., 2010). This shows that the skull breadth was broader in the Gwembe Valley Dwarf goat than was observed in the Morkaman and Tuj sheep. The cephalic index in the Gwembe Valley Dwarf goat was negatively correlated with the skull length and no correlation with the skull breadth was observed. This finding was the opposite of what was observed in the Kagani goat (Sarma, 2006) where the cephalic index was positively correlated with the skull breadth. The basal length in the present study was 12.80 ± 0.80 cm, a value that was shorter than the equivalent 14.88 ± 1.62 cm and 23.40 cm in WAD goat (Olopade and Onwuka, 2005b) and Kagani goat (Sarma, 2006), respectively. The basal length was positively correlated with the skull length similar to what was observed in the Kagani goat (Sarma, 2006). The greatest neurocranium breadth and the upper neurocranium length were 5.85 ± 0.23 cm and 9.02 ± 0.52 cm respectively for the Gwembe Valley Dwarf goat. These values were very similar to what was observed in the Morkaman sheep (Özcan *et al.*, 2010) whose values were 6.01 ± 1.20 cm and 8.97 ± 1.93 cm for the greatest neurocranium breadth and the upper neurocranium length, respectively. The median frontal length in the present study was 8.58 ± 0.64 cm and the cranial index was 66.49 ± 5.43%.

The mean foramen magnum height and the greatest breadth were 1.62 ± 0.10 cm and 1.83 ± 0.12 cm, respectively. The equivalent in goats was 1.72 ± 0.11 cm and 1.67 ± 0.16 cm for the height and the greatest breadth in WAD goat (Olopade and Onwuka, 2005a). From the above values, it was observed that the foramen magnum had different dimensions from what was observed in the WAD goat (Olopade and Onwuka, 2005b). The foramen magnum's horizontal diameter (breadth) was longer than the vertical diameter (height) in the Gwembe Valley Dwarf goat similar to the findings in the Morkaman sheep (Özcan *et al.*, 2010). The foramen index for the Gwembe Valley Dwarf goat was 88.49 ± 5.61% and similar to the value that was obtained in the mole rat which was 88.41% (Özkan, 2007). The equivalent in WAD goat was 102.5% (Olopade and Onwuka, 2005). The area of the foramen magnum in the Gwembe Valley Dwarf goat was 0.74 ± 0.08 cm^2. This area was smaller compared to what was observed in the Kagani goat (Sarma, 2006) whose foramen magnum was 2.53 cm^2.These differences suggests that the diameter of the medulla oblongata in the Gwembe Valley dwarf goat is smaller than the equivalent diameter in Kagani goat. Therefore the findings may necessitate a comparative morphometrical study of the diameter of the medulla oblongata and spinal cord area in this goat breed (Dyce *et al.*, 1996).

The dental length in the present study was 7.76 ± 0.54 cm and was shorter than what was observed in the Rasquera goat (Parés, 2013) which was 12.20 ± 5.81 cm. The oral palatal length and the lateral length of premaxilla in the Gwembe Valley Dwarf goat were 6.12 ± 0.39 cm and 5.53 ± 0.42 cm, respectively. The equivalent values in Tibetan Gazelle (Zhu, 2012) were 7.31 ± 0.15 cm and 4.15 ± 0.15 cm, respectively. The lateral length of premaxilla was longer than that of the Tibetan Gazelle. The length of the maxillary tooth row in this study was 4.78 ± 0.45 cm and much lower than the equivalent in Rasquera goat (Parés, 2013) whose length was 6.79 ± 4.41 cm.

The greatest inner width of the orbit and the greatest inner height in the Gwembe Valley Dwarf goat were 3.11 ± 0.18 cm and 3.15 ± 0.13 cm, respectively. The equivalent in Tibetan Gazelle was 3.87 ± 0.06 cm for the greatest inner width and 3.34 ± 0.08 cm for the greatest inner height of the orbit. The orbital index was 99.10 ± 7.54% and the shape of the orbital rim was circular similar to what observed by Sarma (2006) in Kagani goats. The mean orbital area was 7.69 ± 0.51cm^2, twice that which was observed in Kagani goats (Sarma, 2006).

The facial length and the facial index in the present study were 9.62 ± 0.51 cm and 58.5 ± 3.46 cm, respectively. The facial index was positively correlated both to the skull breadth and skull length ($p < 0.01$) in this study. The equivalent values of the facial length and facial index in goats were 13.20 cm and 13.48cm, respectively, observed in Kagani goat by Sarma (2006). The facial breadth in the Gwembe Valley Dwarf goats was lower than that reported for the Xisqueta sheep (Parés *et al*, 2010). In this study, the greatest length and the greatest breadth of the nasal bone were much lower compared to those recorded in Tuj sheep (Özcan *et al.*, 2010). The greatest length and greatest breadth of the nasal bone in the Gwembe valley were both less than those reported for the Tuj sheep (Özcan *et al.*, 2010). The results suggest that the Gwembe Valley Dwarf goat had a shorter and a narrower nasal portion than the Tuj sheep

The Gwembe Valley Dwarf goat had a mean least diameters of the horn core base (2.59 ± 0.36 cm) which was longer than the reported length in the Tibetan Gazelle (0.43 ± 0.04 cm) by Zhu (2012). On the other hand, the distance between horn tips was slightly two times shorter than what of the Tibetan Gazelle (Zhu, 2012).

In general, based on the classifications of goat skulls according to Aparicio (1960), who classified skulls with cephalic and facial indices with values around 50% or slightly greater as mesocephalic and mesoprosopic respectively, the Gwembe Valley Dwarf goat skull may be classified as mesocephalic (cephalic index 54.4 ± 3.37%) and mesoprosopic (facial index 58.5 ± 3.46%).

5.2 Comparative skull morphometrics of male and female goat.

Sexual dimorphism is one of the morphological features closely related with ecological and behaviour adaptation in mammals (Ralls, 1977). In most ungulates where horns are used for fighting and self defence, there has been a marked distinction between male and female animals based on the horns (Jaslow, 1989). However, in certain animals like carnivore, craniometric (morphometric) studies have proved useful in investigating sexual dimorphism (Ewer, 1973; Jaslow, 1989). Most recently, craniometrical studies have been extended to investigate differences in sex-specific skulls in goats as well (Carné *et al.*, 2007). However, hitherto no information exists as regard to small ruminants and in particular the Gwembe Valley Dwarf goat of Zambia regarding sexual dimorphism based on the skull morphology. Most of the studies about sexual dimorphism associate with the type of reproduction (Jarman, 1983; Clutton-Brock *et al.*, 1980), habitat (Geist and Bayer, 1988), type of fight (Schaffer and Reed, 1972), and its evolutive significance (Janis, 1982; Schaffer, 1968).

In this study, no morphometrical skull conformation differences between males and females in Gwembe Valley Dwarf goat based on the non-parametric One-way analysis of variance (F=1.104; p = 0.317) were observed. However, the non-parametric One-way analysis of variance on the horn parameters showed that significant (F= 4.752; p= 0.006) differences does exist between sexes of the Gwembe Valley Dwarf goat. The horn parameters that had strong influence on the sex dimorphism observed were the horncore basal circumference (-0.93511, Can 1) and the length of the horncore on the front margin (1.23905, Can 1), respectively, from the canonical correspondence analysis. These findings are consistent with what was observed in the Spanish *Capra pyrenaica,* where the horn parameters showed a high degree of sexual dimorphism, both in thickness and in length and shape, with these traits being up to ten times larger in males than females (Fandos *et al.,* 1989). Furthermore, it was observed that the short skull length (skull parameter 4) had some minimal contribution to the sexual dimorphism in the Gwembe Valley Dwarf goat based on the principal components analysis results. These findings could be due to the type of reproduction where bucks to does ratios are high (polygamy) as farmers naturally will opt to sell a buck than a doe. Sexual dimorphism centered the around horn characteristics due to strong polygamy has been proved in the genus *Capra* (Schaffer and Reed, 1972; Schaffer, 1968) as well as in the *Capra pyrenaica species* (Alvarez, 1990).

In addition the type of fights among male goats that ensue around territorial dominance may contribute to this phenomenon where horns are seen as a major discriminator in the comparative craniometry of the male and female Gwembe Valley Dwarf goat (Schaffer and Reed, 1972).

5.3 Applied clinical anatomy of the head of the Gwembe Valley Dwarf goat

The distance from the facial tuberosity to the infra-orbital canal in the Gwembe Valley Dwarf goat and this was higher than the value reported in Markhoz goat (Goodarzi and Hosseini, 2013). This difference was statistically significant ($p < 0.05$, two-tailed). The length of this distance was similar to what was observed in goats from the middle regions of Nigeria (Samuel *et al*., 2013). In the Gwembe Valley Dwarf goat, the distance from the infra-orbital canal to the root of the alveolar tooth (1.13 ± 0.11 cm) was lower than the range reported in the West African Dwarf (WAD) goat ($1.3\text{-}1.6 \pm 0.21$ cm) reported by Olopade and Onwuka (2005a). Since the facial tuberosity is a vital and prominent feature as a guide in tracking the infra-orbital nerve which is blocked in order to bring about the necessary desensitization of the skin of the upper lip, nostril and face at the level of the infra-orbital foramen ipislaterally, the findings in the present study are of clinical significance in relation to the infra-orbital nerve block (Hall *et al.*, 2000). The injection of a local anaesthetic agent within the canal through the infra-orbital foramen leads to the analgesia of the incisor, canine and the first two premolar teeth which can allow extraction of any of these teeth. In this study, the infra-orbital foramen was observed to be located directly dorsal to the second or junction of the first and second upper premolar similar to what was observed in the black Bengal goat

(Uddin *et al.,* 2009). This information will prove a vital guide to regional anaesthesia involving the areas innervated by the infra-orbital nerve in the Gwembe Valley Dwarf goat.

The distance between the lateral alveolar root to the mental foramen in the Gwembe Valley Dwarf goat (1.58 ± 0.19 cm) was comparable to what was observed in the WAD (1.56 ± 0.22 cm) and Markhoz (1.58 ± 0.11 cm) goats, respectively (Olopade and Onwuka, 2005a; Goodarzi and Hosseini, 2013). This distance in the present study, was lower than the equivalent observed in the Iranian Native goat (2.40 ± 0.26 cm) by Monfared (2013). The knowledge on this landmark is vital because injection of local anaesthetic drugs can be made in the rostral aspect of the mandibular canal through the mental foramen to the mandibular nerve block in the mental zone. This ensures the loss of sensation of the lower incisors, premolars and lower lip on the same side during dental extraction and treatment of tooth injuries (Hall *et al.,* 2000).

The mandibular length in the study was lower than the values obtained in the WAD and Markhoz goats, respectively (Olopade and Onwuka, 2005 ; Goodarzi and Hosseini, 2013). On the other hand, the maximum mandibular height of the Gwembe Valley Dwarf goat was comparable to the reported value WAD goat and lower than the Markhoz goat (Goodarzi and Hosseini, 2013). In this study, the distance of the caudal border of the mandible to the level of the mandibular foramen, and the distance from the mandibular foramen to the border of the mandibular angle were lower than the values reported for the Markhoz goat (Goodarzi and Hosseini, 2013). These parameters are of clinical importance as they aid in the regional anaesthesia of the mandibular nerve block, necessary for the desentization of all the teeth on the lower jaw side of the block (Hall *et al.*, 2000). The distance of the mandibular foramen to the base of the mandible in the Gwembe Valley Dwarf goat and the distance of the mandibular angle to below the mandibular foramen were both lower than the reported equivalent lengths in the WAD and Markhoz goats (Olopade and Onwuka, 2005a; Goodarzi and Hosseini, 2013) for the distance of the mandibular foramen to the base of the mandible. The distance of the mandibular angle to below the mandibular foramen in the Gwembe Valley Dwarf goat was lower than the length reported in the WAD goat (Olopade and Onwuka, 2005a) but higher than the value reported in the Markhoz goat (Goodarzi and Hosseini, 2013).

The distance of the condyloid fossa to the base of the mandible in the Gwembe Valley Dwarf goat was higher than what was observed in the WAD goat by Olopade and Onwuka (2005a). On the other hand, the same distance was found to be lower than was observed in the Markhoz goat (Goodarzi and Hosseini, 2013)**.** In this study, the distance of the condyloid fossa to the maximum height of the mandible was lower than that observed in both the WAD and Markhoz dwarf goats. Additionally, both the distance of the condyloid fossa to the base of the mandible and the distance of the condyloid fossa to the maximum height of the mandible were lower in the present study compared to the equivalent values observed in Mehraban sheep (Karimi *et al.,* 2012). These parameters are vital landmarks in carrying out a mandibular nerve block which is performed by injecting an anaesthetic agent on the medial aspect of the mandible which when done successfully produces desensitization of the lower jaw with its teeth and the lower lip (Hall *et al.,* 2000).

The differences observed in the morphometric and the applied anatomy of the head measurements of the Gwembe Valley Dwarf goat with other goats and dwarf goats reported in literature could be due to the adaptations of skull structures to the environmental factors obtaining in these different geographic locations where the goats are found. This kind of adaptation has been reported in Eurasian wild boar which were of the approximate same age based on similar levels of tooth wear but showed skull size variation linked to their geographic location (Albarella *et al.,* 2009).

5.4 Gross morphology of the Gwembe Valley Dwarf goat skull

This part of the study investigated the morphology of the Gwembe Valley Dwarf goat skull systematically and by examination of the frontal, lateral, basal and the caudo-dorsal and nuchal surfaces. Due to the lack of skull morphology data on any Zambian goat breed, literature on skull morphology of ruminants from a variety of other sources was used for comparison with the findings in this study**.**

The frontal surface was constituted by the frontal, parietal, nasal and incisive bones. The frontal bone comprised the largest part of the frontal surface, though it never extended up to the caudal extent of the skull as observed in cattle (Sisson and Grossman, 1975). The frontal eminence was present on the midline, at the middle of the frontals. Caudolaterally, the eminence continued into the cornual process. Morphologically, sexual dimorphism was evident in the frontal bones grossly. Females had a slightly straight frontal plain while the longitudinal convexity of the frontal bone in males was accentuated between the horns. This phenomenon was similar to what was observed in Sahel goat ecotypes in Nigeria (Shawulu *et al.*, 2011). The supraorbital foramina were seen piercing the frontal bone each lying at the dorsolateral aspect and located equidistant from the interfrontal suture, approximately 2cm away from the dorsal rim of the bony orbit similar to what was reported in Kagani goat (Sarma, 2006). Notable were the presence of the accessory supraorbital foramina in some skulls, depicting variation within the specie. Such accessory foramina were seen in Asam goats (Borthakur, 1990) and some Sahel goat ecotypes (Shawulu *et al.*, 2011). The interfrontal suture was zigzag and the fronto-nasal suture appeared serrated and "V" shaped similar to what was reported in Kagani goat (Sarma, 2006). In the Gwembe Valley Dwarf goat, the maximum width of the frontal surface was noticed at the level of the dorso-caudal margin of the orbits as reported in Markhoz goat (Goodarzi and Hoseini, 2014)

The nasal bones were convex at the dorsal surface and broader proximal to the fronto-nasal suture. Rostrally, the nasal bones tapered to a point and appeared notched. The internasal suture was straight, similar to the findings reported in Kagani goat (Sarma, 2006) and concurs with that of the ox reported by Sisson and Grossman (1975).

The lateral surface was composed of the temporal, the zygomatic, lacrimal and the maxilla bones. The temporal crest ended into a blunt tubercle caudo-lateral to the external auditory meatus as in cattle (Raghavan, 1964) and in Kagani goat (Sarma, 2006). The temporal fossa was extensive and shallow as reported in the Assam goat (Borthakur, 1990). The temporal bone consisted of the distinct squamous, tympanic and petro-mastoid parts. As reported by Sisson and Grossman (1975), the squamous part resembled that of the ox, and had a notch through which the external auditory meatus protruded. The facial tuberosity was placed at the junction of the 3rd and 4th cheek teeth (upper) premolar dissimilar to what was reported in Kagani goat where the facial tuberosity was placed at the junction of the 4th and 5th premolar teeth (Sarma, 2006). The infraorbital foramina were single on either side, placed on a depression. Cranial to the infraorbital foramen was a shallow fossa with small perforations that looked like foramina. The orbital rims were complete, oval and the caudo-dorsal end of the rims was serrated. As was reported in Kagani goat (Sarma, 2006) and Assam goat (Borthakur, 1990), the orbits of the Gwembe Valley Dwarf goat were directed laterally. The basisphenoid bone had a sharp median ridge on its body as was reported in small ruminants (Popesko, 1975). The orbital surface of the lacrimal bone was smooth and marked off from the facial surface by a dentate orbito-facial crest. A shallow fossa leading to the lacrimal canal was observed just behind the crest. The foramen ovale was located in the caudal part of the pterygoid bone similar to the Kagani (Sarma, 2006).

The basilar part of the occipital bone was straight, and bound rostro-caudally by two pairs of muscular tubercles, with the rostral tubercles of the Gwembe Valley Dwarf goat being larger similar to what was reported in Mehraban sheep (Karimi *et al.,* 2011), but the opposite of what was found in Kagani goats where the caudal tubercles were reported to be larger (Sarma, 2006). The median occipital crest was well developed in the Gwembe Valley Dwarf goat. The occipital condyles met ventrally forming a “U”-shaped intercondyloid cleft. The paracondylar (jugular) processes were curved latero-ventrally and tapered to a point. The tympanic bullae were small and compressed laterally as reported by Sarma (2006) in Kagani goats. The pterygoid bone was broad above and narrow below ending in a sharp-pointed hamulus similar to what was reported in Kagani goat (Sarma, 2006).

The external acoustic process was directed almost straight outward. A curved plate extended ventrally from it and joined the bulla ossea medially, completing the deep concavity which receives the articular angle of the hyoid bone. The palatine portion was “U”- shaped with a straight and smooth median palatine suture. The palatine portion was “U”- shaped with a straight and smooth median palatine suture. The transverse palatine suture was “V”-shaped and serrated, lying over the major palatine foramen. The dorsal border of the palatine bone was united with sphenoid bone and perforated by a sphenopalatine foramen as was the case with Kigani goat skulls (Sarma, 2006) and in Mehraban sheep (Karimi, 2011). A well developed and prominent interalveolar margin was observed in the Gwembe Valley Dwarf goat.

The caudo-dorsal and nuchal surface was composed of the occipital, interparietal, parietal, frontal bone and the squamous part of the temporal bones. The occipital bone formed the entire nuchal surface. The caudo-dorsal and nuchal view was defined by two prominences, rostrally the frontal eminence and the external occipital protuberance on the caudo-ventrally. The frontal eminence was generally prominent in the Gwembe Valley Dwarf goat and very prominent in males. From the frontal prominences arose at their extremities the cornual processes. These cornual processes were directed backwards, a characteristic of the Gwembe Valley Dwarf goat which has also been reported by Mwenya (2001). At the base of the cornual process latero-ventrally and at the end of the temporal was a depression termed the caudofrontal depression, similar to what was reported in three different goat breeds in Nigeria (Olopade, *et al.*, 2006a). The external occipital protuberance was sharp and pointed. Ventrally, the median occipital crest extended towards the foramen magnum as was reported in Kagani goats (Sarma, 2006). The occipital condyles were further apart and the articular surfaces were divided into upper and lower parts. The mastoid foramen was at the junction of the occipital and temporal bones and it appeared small, similar to what was reported in a bovine skull (Sisson and Grossman, 1975).

In general, the differences observed in the Gwembe Valley Dwarf goat with other goats could have been due to the epigenetic factors and the habitat in which these goat breeds are predominantly found. Pankakoski and Nurmi (1986) observed that skull morphology and relative skull measurements differences of an animal skull were highly dependent on habitat differences as influenced by climatic and geographical factors. In the Gwembe Valley Dwarf goat, the skull dimensions and morphology could have been influenced by the hot and drier climatic conditions obtaining in the study area coupled with scarce grazing lands due to the mountainous nature of the area geographically (Lundu *et al*., 2012).

The study has generated baseline craniometric, clinical aspects of the mandible and the skull, and the skull morphology of the indigenous Gwembe Valley Dwarf goat of Zambia. It is worth noting that the data will be a useful reference as long as there are minimum changes in the environment (climate change) and breeding practices such as cross breeding. This is in tandem with the observation made by Olopade and Onwuka (2007) where they noted that early osteologic support structures for vision and the entire bony apparatus of the skull of animals are adaptational strategies aimed at coping with the environment the animal finds itself. Dunlop (1963) stressed that skull parameters, to an extent, are dictated by the interactions between heredity and environment. Additionally, the equipments used will need to be put into consideration, in this study; the Vernier callipers, an ovinometer and a measuring tape were used. As such this data cannot be comparable to data gathered using other techniques such as X-rays, Computed Tomography (CT scan) among others used in biometrical investigations in other countries.

CHAPTER SIX

6.0 CONCLUSION

The Gwembe Valley Dwarf goat skull biometry was determined at two levels namely, the several craniometry or morphometry, and the skull measurements applicable to the applied clinical regional anatomy concerned with regional anaesthesia of the head region. In addition, the gross morphology of the skull was evaluated.

The skull morphometry study generated a number of that will be useful as baseline data for comparative studies with other indigenous or exotic goat breeds in Zambia. In the Gwembe Valley Dwarf goat, the cephalic index was negatively correlated with the skull length and the basal length was positively correlated with the skull length. The skull of the Gwembe valley may be classified as mesocephalic and mesoprosopic based on the skull indices obtained. Furthermore, sexual dimorphism was morphometrically elucidated and was significant with horn parameters and not the general skull parameters such as skull size, skull length or skull breadth.

The landmarks applicable to the regional nerve blocks around the head such as the infra-orbital, mental and mandibular nerves were determined. Comparatively, these anatomical landmarks in the Gwembe Valley Dwarf goat were more similar to those reported in the West African Dwarf goat (Olopade and Onwuka, 2005a) than those of the Markhoz goat (Goodarzi and Hosseini, 2013), a native dwarf goat of Irania.

Grossly, the morphology of the Gwembe valley skull was comparable with other small ruminants, especially the Kagani goat breed. The sexual dimorphism in the skull grossly existed and was centred on the frontal eminence which was more pronounced in males than female skulls.

6.1 RECOMMENDATIONS

This study is the first of its kind in the Gwembe Valley Dwarf goat in Zambia. Having generated the baseline data, it is recommended that:

1. Further studies must be conducted in order to establish whether ecotypes of the Gwembe Valley Dwarf goats occur across all breed distribution areas in Zambia.
2. Similar biometrical studies be undertaken in other goat breeds such as the Valley goat and the Plateau goat to establish morphological relationships among these breeds in Zambia.
3. Comparative studies in areas of morphometry and applied clinical anatomy of the head in domestic animals in Zambia be undertaken to reduce the information gap as evidenced by lack of literature on these areas peculiar to Zambia.

CHAPTER SEVEN

7.0 REFERENCES

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CHAPTER EIGHT

8.0 ANNEXES

8.1 Comparative descriptive statistics in cm (Females, n=15; Males, n=15)

	Female							Male						
Var.	**Min**	**Max**	**X**	**SD**	**CV**	**W**	**.p**	**Min**	**Max**	**X**	**SD**	**CV**	**W**	**.p**
1	13.0	16.7	15.1	1.319	8.7	0.908	0.125	13.4	16.7	15.0	0.858	5.7	0.944	0.438
2	12.6	16.4	14.3	1.389	9.7	0.897	0.085	12.5	15.8	14.7	0.746	5.1	0.801	0.004
3	11.8	14.5	13.1	0.786	6.0	0.969	0.839	11.6	14.1	12.6	0.757	6.0	0.953	0.573
4	7.7	10.3	9.1	0.789	8.7	0.963	0.742	7.5	10.3	8.2	0.685	8.3	0.783	0.002
5	3.5	4.6	4.0	0.348	8.6	0.956	0.622	3.5	4.3	4.0	0.254	6.4	0.951	0.541
7	7.8	9.8	8.6	0.669	7.8	0.921	0.198	7.5	9.4	8.5	0.534	6.3	0.974	0.917
8	7.7	10.0	9.1	0.680	7.5	0.946	0.464	7.8	9.8	8.6	0.536	6.2	0.939	0.365
9	4.6	5.3	5.0	0.197	3.9	0.951	0.533	4.3	5.2	4.9	0.246	5.0	0.924	0.218
10	5.3	6.4	5.9	0.340	5.8	0.967	0.815	5.3	6.6	6.0	0.369	6.1	0.947	0.484
11	8.2	9.3	8.9	0.342	3.8	0.888	0.063	8.0	10.0	9.1	0.711	7.8	0.928	0.251
12	9.0	10.6	9.8	0.403	4.1	0.981	0.976	8.4	10.3	9.5	0.563	5.9	0.93	0.269
13	9.9	12.0	10.6	0.615	5.8	0.923	0.213	10.0	11.5	10.7	0.443	4.1	0.931	0.285
14	1.9	3.3	2.6	0.369	14.2	0.991	1.000	2.0	2.9	2.6	0.218	8.5	0.948	0.491
15	3.9	5.6	4.8	0.556	11.7	0.943	0.422	4.0	5.5	4.6	0.411	9.0	0.889	0.065
16	7.5	9.9	8.8	0.739	8.4	0.966	0.791	7.7	9.7	8.9	0.578	6.5	0.959	0.671
17	10.1	11.9	11.0	0.658	6.0	0.928	0.251	9.9	11.8	11.1	0.525	4.7	0.94	0.383
18	6.9	8.7	7.9	0.588	7.4	0.923	0.212	6.6	8.5	7.6	0.467	6.1	0.981	0.976
19	5.7	6.8	6.2	0.371	5.9	0.854	0.020	5.1	6.5	6.0	0.377	6.3	0.947	0.484
20	5.1	6.3	5.6	0.439	7.8	0.849	0.017	4.7	6.0	5.5	0.401	7.3	0.936	0.333
21	4.3	5.6	5.0	0.449	9.0	0.918	0.180	4.1	5.3	4.6	0.388	8.5	0.887	0.060
22	2.5	3.1	2.8	0.149	5.2	0.926	0.237	2.6	2.9	2.8	0.097	3.5	0.903	0.107
23	1.5	2.7	2.2	0.443	20.5	0.873	0.038	1.4	2.5	1.9	0.403	20.7	0.887	0.060
24	2.8	3.3	3.1	0.171	5.5	0.952	0.556	2.8	3.4	3.1	0.188	6.0	0.934	0.314
25	2.9	3.2	3.1	0.093	3.0	0.944	0.429	2.8	3.4	3.2	0.167	5.3	0.981	0.973
26	5.4	6.2	5.9	0.223	3.8	0.884	0.055	5.2	6.2	5.8	0.308	5.3	0.924	0.218
27	3.8	4.4	4.1	0.168	4.1	0.942	0.402	4.0	4.3	4.1	0.087	2.1	0.92	0.192
28	4.8	5.9	5.3	0.251	4.7	0.954	0.589	5.0	5.7	5.3	0.177	3.3	0.95	0.522
29	1.6	2.0	1.9	0.106	5.7	0.973	0.897	1.5	2.0	1.8	0.136	7.5	0.913	0.151
30	1.5	1.8	1.6	0.093	5.7	0.93	0.269	1.4	1.7	1.6	0.105	6.6	0.936	0.331
31	2.2	3.9	2.9	0.430	14.7	0.952	0.556	2.7	3.7	3.1	0.318	10.1	0.946	0.461
32	5.5	7.2	6.4	0.416	6.5	0.981	0.976	6.2	7.1	6.8	0.276	4.1	0.928	0.256
33	5.6	6.6	5.9	0.264	4.5	0.795	0.003	5.4	6.0	5.8	0.191	3.3	0.95	0.524
34	7.3	9.1	8.2	0.485	5.9	0.936	0.331	7.6	8.5	8.1	0.283	3.5	0.942	0.413

Var.	Min	Max	X	SD	CV	W	.p	Min	Max	X	SD	CV	W	.p
35	5.4	7.3	6.4	0.479	7.5	0.975	0.922	5.7	6.9	6.3	0.272	4.3	0.949	0.511
36	5.0	6.1	5.6	0.333	5.9	0.938	0.357	5.1	6.0	5.6	0.244	4.4	0.982	0.979
37	1.6	2.5	2.1	0.237	11.1	0.983	0.984	1.7	2.4	2.1	0.232	11.2	0.944	0.433
38	1.7	2.3	2.1	0.189	9.0	0.905	0.112	1.7	2.3	2.1	0.151	7.1	0.961	0.716
39	5.0	5.9	5.5	0.275	5.0	0.963	0.747	5.0	5.9	5.4	0.246	4.5	0.979	0.959
40	0.0	8.0	6.4	1.954	30.5	0.672	0.000	6.8	9.0	8.2	0.615	7.5	0.94	0.382
41	1.8	2.9	2.4	0.328	13.8	0.962	0.732	2.2	3.2	2.8	0.260	9.3	0.982	0.982
42	1.5	2.1	1.9	0.208	11.2	0.897	0.085	1.9	2.5	2.1	0.169	7.9	0.905	0.114
43	0.0	6.8	4.9	1.611	33.1	0.817	0.006	4.5	8.4	6.0	1.089	18.2	0.928	0.251
44	4.5	7.9	5.9	0.939	15.9	0.968	0.830	6.0	8.9	7.0	0.748	10.7	0.881	0.048

In table above: X: Mean, **SD**: Standard Deviation, **CV**: Coefficient of Variation, W: Shapiro-Wilk, **p:** Probability.

Key to variables: Von Driesch (1976) numeration was used except for variable 44 which was adopted from Zhu (2012) as indicated in figures 5-8 under materials and methods (see text).

8.2 Component loadings for PCA in sexual dimorphism investigation.

	PC1	PC2	PC3
1	0.263	0.359	-0.330
2	0.337	0.282	-0.325
3	0.110	0.295	0.335
4	0.012	0.281	**0.498**
5	0.048	0.108	-0.080
7	0.106	0.143	0.161
8	-0.051	0.133	0.331
9	0.018	0.033	0.034
10	0.064	0.034	-0.092
11	0.042	-0.056	0.301
12	0.061	0.111	0.171
13	0.145	0.091	-0.097
14	0.064	0.090	0.007
15	0.093	0.127	0.005
16	0.144	0.153	-0.189
17	0.181	0.116	0.031
18	0.124	0.214	0.027
19	0.069	0.164	0.013
20	0.094	0.121	0.038
21	0.062	0.142	0.091
22	-0.001	0.027	-0.002
23	0.062	0.112	0.004
24	0.033	0.040	-0.065
25	0.015	-0.004	0.069
26	0.023	0.061	0.027
27	0.013	-0.002	-0.010
28	0.035	0.051	-0.001
29	-0.016	0.002	-0.002
30	-0.017	0.002	-0.011
31	-0.043	-0.098	-0.131
32	0.090	-0.050	0.032
33	0.023	0.038	-0.031
34	0.045	0.130	0.011
35	0.082	0.125	0.049
36	0.057	0.094	-0.004
37	0.013	0.039	0.037
38	0.025	0.025	0.003
39	0.055	0.083	0.053
40	**0.541**	**-0.439**	0.091
41	0.072	-0.113	0.132
42	0.043	-0.047	-0.038
43	**0.506**	-0.252	0.092
44	0.264	-0.161	0.159

8.3 List of published articles from this masters' research work

1. **Kataba A**, E.S Mwaanga, H Simukoko and C.P.M Parés, 2014. Clinical anatomy of the head Region of Gwembe Valley Dwarf goat in Zambia. International Journal Veterinary Science, 3(3): 142-146. www.ijvets.com.

2. Parés C.P.M, **A. Kataba**, E.S Mwaanga and H Simukoko, 2014. Gynomimicry in the Dwarf Gwembe breed from Zambia. Research, 1: 809.