3. MATERIALS AND METHODS

3.1 Materials

Archaeological human remains and cultural artifacts excavated from various parts of Botswana are submitted to the BNMMAG in Gaborone for storage. However, materials excavated by archaeologists from UB are kept at the Archaeology Division of UB for some time before being forwarded to the museum. Materials used for this study were all obtained from these two institutions. It was mostly through the literature and the author's knowledge that it became known how many burials had been unearthed from which sites. Neither the BNMMAG nor UB have catalogues for burials. The situation at the museum is worsened by mixing up individual skeletons in the past, when rearranging the storage facilities. Most of the boxes containing human burials are not labeled as such and therefore many boxes had to be unpacked in search of human remains. The skeletons from Toutswemogala were labeled on paper that was then stuck using tape. Most of the tapes had fallen off and thus making it even more difficult to identify the skeletons according to Lepionka's system. It will not come as a surprise should more burials be found after completion of this study, because the author's access to the BNMMAG and UB storage facilities was limited.

The literature was used to cross check the number of burials that were reported from different sites, and to use that as a basis for which boxes to search for relevant materials. For instance, Denbow (1983a) reported five burials from Taukome and therefore the search for Taukome burials was conducted until all burials had been found. On the other hand, other burials are known to have been excavated in the past especially by the university researchers but could not be found. In 1997 and 1998, for example, two burials were excavated at Mosu 1 and Mosu 3 respectively (Reid and Segobwe 1997; 2000) but the burial from Mosu 1 has been misplaced and was therefore not included in the current study sample. Table 3.1 summaries a list of burials known to have been excavated at various sites some of which were not available for analysis. The total number of burials reported from each site, date of excavation and the researcher who excavated the burial(s) is indicated where possible.

As mentioned previously, many of the skeletons were unfortunately mixed/commingled and some are missing. These are obviously difficult to analyse, but an attempt was made to establish the minimum number of individuals using mandibles or maxillae of incomplete and commingled remains.

During the winter season of 2002 the author set out with a team of archaeology students and professionals from Botswana and the USA on an excavation expedition in Bosutswe. The season produced 13 burials that were then exported to Pretoria along side skeletons from other sites for analysis. The remains of one adult from Mosu and an infant skeleton from Dikalate were studied at the UB where they were currently being in stored.

Table 3.1. Summary of burials obtained from different sites.

Site name	**Reported Burials**	**n**	**Date Excavated**	**Principal Researcher**	**Current Location**
Bosutswe	14	11	2001-2	JR Denbow	BNMMAG
Thatswane	6	4	1979	JR Denbow	BNMMAG
Taukome	6	6	1979	JR Denbow	BNMMAG
Lechana	2	0	1979	JR Denbow	BNMMAG
Maiphetwane	?	0	1979	JR Denbow	BNMMAG
Phate Hill	1	0	?	AK Segobye	BNMMAG
Toutswemogala	?	31	1970s	L Lepionka	BNMMAG
Kgaswe B-55	27	27	1983	JR Denbow	BNMMAG
Mosu 3	2	1	1998	A Reid	UB
Thataganyane	1	1	1992	?	BNMMAG
Kaitshe	1	0	1997	A Reid	UB
Dikalate	1	1	1999	A Reid	UB
Serowe Hill	?	1	1978	D Schemers	BNMMAG
Swaneng Hill	?	1	1989	A Lock	BNMMAG
Total	?	84			

n - number of skeletons included in the current study sample

?- information not known

3.2 Age estimation

Introduction

Estimation of age from the human skeleton and dentition is important in any study of palaeodemographic nature. The use of human hard tissue to estimate age was popularised some decades back (e.g., Todd and Lyon 1924; 1925; Massler et al. 1941; Schour and Massler 1941; Anderson et al. 1976; Fazekas and Kosa 1978). It continues to form a significant part of the physical anthropology literature (e.g., Ferembach et al. 1980; Van Beek 1983; Krogman and Iscan 1986; Ubelaker 1987; 1989a; İşcan 1989; İşcan and Kennedy 1989; Konigsberg and Frakenberg 1992; Novotny et al. 1993; Scheuer and Black 2000).

Skeletal aging techniques range from simple observation of gross morphology and metric evaluation to more complex studies of bone histology and cementum annulation and others (Ferembach et al. 1980; Krogman and İşcan 1986; İşcan 1989; İşcan and Kennedy 1989; Maples 1989; Novotny et al. 1993). Gross morphological observations techniques include, among others, changes in the pubic symphysis, closure of cranial sutures, degeneration of sternal ends of ribs, development and eruption of teeth, dental wear and fusion of epiphyses (Todd and Lyon 1924; 1925; Meindl and Lovejoy 1985; 1989; Krogman and İşcan 1986; İşcan 1989; Novotny et al. 1993; İşcan et al. 2000; Loth and İşcan 2000a). Metric evaluation involves the measurement of maximum lengths of various long bones and matching the measurements to dental ages (Fazekas and Kosa 1978; Sundick 1978; Ubelaker 1987; Kosa 1989).

It is important that each population group be studied so as to better understand ages at which different teeth erupt within that group. MacKay and Martin did one of the earliest works of determining ages at which teeth erupt among the Bantu people of Africa in 1952. Their study included a total of 680 boys and 603 girls all under the age of 20 years. The children were from the Msambweni area in Kenya (MacKay and Martin 1952). Comparison of their results to those from other areas revealed that deciduous teeth of the Bantu children erupt slightly later than and were shed a bit earlier than those of their British counterparts. Early loss of deciduous teeth meant that the Bantu children then had permanent teeth appearing slightly earlier than those of other races. Moreover, the processes occurred slightly earlier in females than in males (MacKay and Martin 1952; El-Nofely and İşcan 1989).

Various bones or parts thereof attain maturity stages at different times. During early years of life, bones are characterized by growth through increment in dimensions of individual bony masses and through fusion of related bony masses to form single bone units (Fazekas and Kosa 1978; Krogman and İşcan 1986; İşcan 1989; Ubelaker 1989a; İşcan and Kennedy 1989; Loth and İşcan 2000a; Scheuer and Black 2000). Once adulthood is reached, remodeling and resorption becomes the main activity in bone tissue. Processes associated with changes in the morphology of bone as a result of age are commonly referred to as degenerative conditions.

Consequent to the fact that various bones mature at various ages, numerous techniques have been developed to estimate age from fetal stages to old ages. It has been recognized that some morphological features are only reliable and accurate age indicators within a specific period of the life span and may become less reliable or completely irrelevant in some periods. For example, lengths of long bones are accurate when estimating ages of fetuses and young individuals and their reliability decreases with age so that by the late adolescent they become useless (Sundick1978; Fazekas and Kosa 1978; Ferembach et al. 1980; Johnston 1982; Krogman and İşcan 1986; Ubelaker 1987; 1989b; Scheuer and Black 2000). Like wise, the remodeling of the true ribs does not take place until about the early twenties and only become more reliable and accurate with increase in age (İşcan 1989; Oettlé and Steyn 2000; Loth and İşcan 2000a).

The most highly accurate method of age determination on immature human skeletal remains is the assessment of dental development and eruption (Massler et al. 1941; Schour and Massler 1941; MacKay and Martin 1952; Ubelaker 1987; 1989b; Loth and İşcan 2000a). Initial calcification, eruption and completion of roots are good indicators of age as these processes occur within a specific period of time with slight differences between males and females and between populations (Van Beek 1983; El-Nofely and İşcan 1989; Loth and İşcan 2000a). The sequence of dental development and eruption is well known and it has been found to be fairly consistent throughout different racial groups. There may be slight variations in the timing of eruption though (Van Beek 1983; Ubelaker 1989a; Loth and İşcan 2000a).

Guidelines for determining dental age in form of charts have long been established, by researchers like and Massler and coworkers (1941), Schour and Massler 1941 and Ubelaker (1989a). These charts have been used extensively in the literature (e.g. Krogman and İşcan 1986; İşcan 1989; Loth and İşcan 2000a; Scheuer and Black 2000) and are thus regarded as reliable and accurate tools to assist in dental aging. It is worth noting that this chapter will only focus on those techniques that have been used in the current study to estimate age.

Any attempt to reconstruct the life style of human from skeletal and dental remains is clouded by problems and limitations. Problems encountered in age estimation from skeletal and dental remains have been discussed in detail by numerous authors (e.g., Buikstra and Konigsberg 1985; Krogman and İşcan 1986; Ubelaker 1987; İşcan and Kennedy 1989, İşcan 1989; Maples 1989; Loth and İşcan 2000a). Variations in times of reaching maturity or specific developments exist between populations and hence standards for age estimation are population and sex specific (MacKay and Martin 1952; Ubelaker 1978; Buikstra and Konigsberg 1985; Krogman and İşcan 1986; İşcan and Kennedy 1989; Loth and İşcan 2000a). Therefore, when estimating age it is important to use a reference sample that is as close to the study sample as possible. Variations also exist between sexes within the same population. When dealing with skeletal material whose sex cannot be determined, results of age estimates should be of a range that encompasses both sexes (Krogman and İşcan 1986; Ubelaker 1987; İşcan 1989; Loth and İşcan 2000a). Furthermore, there has to be an emphasis on the use of various methods and bones available in order to limit the effects of inaccuracy detected in each method as well as to minimise inaccuracy resulting from variations between populations and reference samples populations (Ferembach et al. 1980; Konigsberg and Frakenberg 1985; Maples 1989).

Newborn/fetal

Lengths of long bones are commonly used to estimate age of newborn/fetal skeletons, for two main reasons. Firstly, they provide results of high accuracy with a margin of error of one month (Sundick 1978; Fazekas and Kosa 1978; Krogman and İşcan 1986; Ubelaker 1987; 1989b; Kosa 1989; Scheuer and Black 2000). Secondly, long bones preserve better than tooth germs in the archaeological record. For instance, in the current study, tooth germs were hard to come by whereas long bones were more readily available. The Fazekas and Kosa (1978) standards are used worldwide as they are based on adequate samples and they have been proved to be highly accurate. This study used the Fazekas and Kosa (1978) standards.

Another method used to assist in aging newborn/fetal remains is assessment of fusion of bony masses forming the temporal bone. During the eighth fetal month, the tympanic ring fuses to the squama (Fazekas and Kosa 1978; Kosa 1989; Scheuer and Black 2000) so that at birth two bony masses, the petromastoid and the squamotympanic represent the temporal bone.

Zero to five years

The most important age related skeletal changes during the first five years of life is the continued development and subsequent eruption of deciduous teeth (Massler et al. 1941; Schour and Massler 1941; Van Beek 1983; Krogman and İşcan 1986; Ubelaker; 1989a; 1987; Iscan 1989; İşcan and Kennedy 1989; Scheuer and Black 2000). Eruption of deciduous teeth begins with the central incisors of the mandible at about six months, followed by lateral incisors at approximately nine months, first molars at 12 months, canines and second molars at 18 months and 24 months respectively. At approximately three years all deciduous teeth are in occlusion and permanent teeth do not show until the sixth year of life (Massler et al. 1941; Schour and Massler 1941; Ubelaker 1987; 1989a; van Beek 1983; Loth and İşcan 2000a). An acknowledged dental development and eruption chart developed by Ubelaker (1989a) was used to determine dental ages of immature skeletons. The age estimates were made broader to encompass sex differences.

Long bone lengths continue to be very useful age indicators during these years. In cases where long bones were not present (e.g., Bosutswe Burial 4), cranial measurements were used as substitutes. This individual is represented by a partially complete calvarium only. Cranial measurements are less accurate than long bone lengths and thereby producing slightly wider age ranges. The data used for craniometric aging was obtained from K2 skeletons (Steyn and Henneberg 1997a).

Developments occurring during the first year of life are that the left and right halves of the mandible fuse to each other at about six months and the posterior fontanelle closes (Loth and İşcan 2000a; Scheuer and Black 2000). The petromastoid and squamotympanic parts fuse to each other so that by the end of the first eighteen months there is one bony mass making up the temporal bone. On the sphenoid bone, the greater wings fuse to the body (Scheuer and Black 2000).

After birth the anterior fontanelle reduces in size but does not attain complete closure until about the second year of life (Loth and İşcan 2000a; Scheuer and Black 2000). The metopic suture, which divides the frontal bone into left and right parts between the nasion and the bregma closes at approximately two to three years but in some rare instances, a patent metopic suture just above the nasion, may remain open throughout adulthood (Loth and İşcan 2000; Scheuer and Black 2000). Between one and three years the lateral parts of the occipital bone fuse to the squama so that the occipital bone is represented by two bony masses at the end of the third year of life.

On the vertebral column, between the third cervical vertebra and the fifth lumbar vertebra, three bony masses represent each segment at birth. Neural arches fuse to each other during the first year of life and neurocentral fusion takes place between two and three years. At the end of four years, most vertebral segments are represented by single bony masses (Scheuer and Black 2000).

Five to 15 years

Eruption of permanent teeth is an important characteristic feature between five and 18 years. The sequence of permanent teeth eruption begins with the first molars at approximately six years and follows with eruption of central incisors at six to seven years, lateral incisors at seven to eight years, first premolars at about nine years, second premolars between nine and 11 years. Canines and second molars erupt at about 11 and 12 years respectively (Massler et al. 1941; Schour and Massler 1941; Anderson et al. 1976; Ubelaker 1989a; Van Beek 1983; Hillson 1996; Loth and İşcan 2000a). Third molars are more varied as they may erupt between 17 and 21 years. In some individuals they do not develop at all. The period between six and 11 years is characterised by a mixture of deciduous and permanent teeth with deciduous teeth being replaced by permanent teeth.

Between five and seven years, the lateral parts and basilar part of the occipital bone fuse and hence the occipital bone is represented by one bony mass at the beginning of the eighth year (Scheuer and Black 2000). Lengths of long bones are still good indicators of age during this period.

13 to 20 years

The main process of growth during adolescence is the fusion of epiphyses of major bones and this process takes on a known pattern. The process begins with fusion of the elbow at approximately 12 to 14 years followed by the hip, ankle, knee, wrist and finally the shoulder at about 18 years (Krogman and İşcan 1986; İşcan 1989; Ubelaker 1989b; Loth and İşcan 2000a). By the mid twenties most of the fusion lines are partially or completely obliterated. More detailed descriptions of ages of epiphyseal fusion are provided in the literature (e.g. Ferembach et al. 1980; Krogman and İşcan 1986; İşcan 1989; Scheuer and Black 2000). As mentioned previously, third molars may erupt towards the end of adolescence.

20 years and over

Recent developments in the field of forensic anthropology have revealed that age from mature or adult human skeletal remains can be estimated from the sternal ends of the third to fifth ribs (Maples 1989; İşcan 1989; Loth and İşcan 1994; 1996; 2000a; Oettlé and Steyn 2000). The method was first developed for Americans and it has since been tested on different population groups. A recent case study conducted by Oettle and Steyn (2000) focused on South African blacks to test the degree of accuracy of using rib phase analysis for age determination. Results from this study indicated that among South African black males, initial changes take a bit longer to show but as soon as the process starts, changes occur rapidly (Oettlé and Steyn 2000).

Following the study by Oettlé and Steyn (2000), a model with ribs at different phases for aging purposes was developed. The model is available at the Department of Anatomy, University of Pretoria, and was used in the current study to help estimate ages of adults from Toutswe sites. South African blacks are currently the closest reference material for human skeletal material from Botswana. İşcan

By the end of 25 years all permanent teeth are in occlusion and beginning to show varying degrees of dental wear. The medial end of the clavicle fuses between 25 and 30 years and the sphenooccipitalis at the base of the skull closes between 27 and 30 years (Loth and İşcan 2000a; Scheuer and Black 2000).

Cranial sutures have been used for many decades to estimate age of adults (Todd and Lyon 1924; 1925; Meindl and Lovejoy 1985a; Ubelaker 1987; 1989a; Krogman and

İşcan 1986; Masset 1989; Novotny et al. 1993; Loth and İşcan 1994; 2000a). Closures of cranial sutures are one of earliest features identified as indicators of maturity. The process begins endocranially and continues ectocranially (Todd and Lyon 1924; 1925; Meindl and Lovejoy 1985a; Masset 1989; Krogman and İşcan 1986).

Acknowledged systems of scoring cranial suture closures and converting those scores into age are available in the literature (e.g., Meindl and Lovejoy 1985; Krogman and İşcan 1986; Masset 1989; Novotny et al. 1993; Loth and İşcan 1994; 2000a). The sutures are divided into various parts and scored for the degree of closure on a scale of zero to four. The results are then added to determine a composite score, which is then used the estimate the individual's age (Meindl and Lovejoy 1985a; Krogman and İşcan 1986; Masset 1989; Novotny et al. 1993; Loth and İşcan 2000a).

Problems arising from the use of cranial sutures to estimate age have been discussed extensively in the literature. The rate at which sutures close varies from one individual to the other even if the individuals were drawn from the same population. Some individuals have premature closure while in some old adults the sutures may still be visible. They can only be used to give wide age ranges, as they are varied between individuals and less accurate (Meindl and Lovejoy 1985a; Buikstra and Konigsberg 1985a; Krogman and İşcan 1986; Maples 1989; Masset 1989; Loth and İşcan 1994; 2000a; Konigberg and Frakenberg 1992; 2002).

During adulthood the skeleton undergoes degeneration especially on the vertebral column and major weight bearing joints. Lesions produced by degenerative diseases are not good indicators of skeletal age but they have proved to be useful when usual age indicators have not been preserved. Most degenerative diseases begin in the fourth decade of life but the rates at with lesions develop differs from one individual to the other. Such lesions can give ideas regarding wide possible age ranges. Dental wear is also an indicator of age that can be used in the absence of other age indicators. Dental wear is not an accurate method because of individual variation (Krogman and İşcan 1986; Ubelaker 1989a; Maples 1989; Walker et al. 1991). The rate at which an individual's teeth are worn depends mainly on their diet and therefore if the diet of a community were fairly the same, then they would tend to show fairly similar degrees of dental wear in every age category (Walker et al. 1991).

3.3 Sex determination

Debates regarding estimation of sex of immature individuals from skeletal remains have been on going for sometime now e.g. Saunders (1992). Many sex specific features are absent during childhood and only develop during puberty by hormonal and genetic stimuli (St Hoyme and İşcan 1989). Research has been done on the so-called sexually dimorphic traits of the mandible of juveniles (e.g., Schutkowski 1993; Loth and İşcan 2000b). While some anthropologists argue that the shape of the chin of juveniles is a reliable sex indicator (Schutkowski 1993; Loth and Henneberg 2001; Loth and İşcan 2000b), recent work has shown that the trait was more accurate on males than on females but that its overall accuracy is very low (Scheuer 2002). Moreover, the method is inconsistent. Although standards for determining sex of fetal and infant remains are available, their accuracies are often too low and therefore do not give one strong confidence for accurate results. As a result no attempts were made to determine sex of infants, juveniles and subadults.

The pelvis

Determination of sex from skeletal remains is most highly accurate and dimorphism readily observable from the pelvic bones of mature individuals (Washburn 1949; Singh and Potturi 1978; Kelley 1979; Ferembach et al. 1980; Brothwell 1981; Krogman and İşcan 1986; St Hoyme and İşcan 1989; Loth and İşcan 2000b). It is on the pelvis that sex specific changes take place as females mature in preparation for child bearing. The changes may be initially subtle but become very distinct towards the end of the second decade of life. The female pelvis is characterised by a wide sciatic notch, wide subpubic angle, short and broad sacrum, a small acetabulum, and other features (Singh and Potturi 1978; Kelly 1979; St Hoyme and İşcan 1989; Krogman and İşcan 1986; Loth and İşcan 2000b)

On the male, the sciatic notch is narrow and so is the subpubic angle and the sacrum is long and thin. The acetabulum of a male is larger by comparison to that of a female. If all or most of the pelvic bones are present and can be articulated, a male will be marked by a heart shaped pelvic inlet and a female has an oval inlet shape (Washburn 1949; Krogman and İşcan 1986; St Hoyme and İşcan 1989; Loth and İşcan 2000b). The presence of parturition scars is useful in identifying females who had been pregnant before. However, its absence does not necessarily mean the individual was a male as it has been found that not all females develop such scars.

Cranium

Certain features of the skull of an adult are instrumental in identifying sex of an individual. A study done by De Villiers (1968a) on South African blacks (Bantu-speaking Negro) identified several sexually dimorphic features on the skull. The features are either morphologic or metric. Some of the features identified include rounded supraorbital margins, robust muscle attachments, prominent glabella, large supra orbital ridges all of which are indicative of a male. A female, on the other hand, will have sharp supraorbital margins, a small mastoid process, etc (De Villiers 1968a; Krogman and İşcan 1986; Loth and İşcan 2000b). In addition to these features, males tend to have large teeth with wide gonials whereas females tend to have small teeth.

On the mandible a squared, or angular, chin is indicative of a male whereas the female chin is rounded (De Villiers 1968a; Loth and Henneberg 1996; Loth and İşcan 2000b). In more recent developments, it has been found that the ramus of the mandible continues to grow straight in adult females while in males it flexes at the occlusal level (Loth 1996; Loth and Henneberg 1996; Loth and İşcan 2000b). The sexual dimorphism of the ramus of the mandible is a fairly new discovery and as such requires more work to improve its accuracy and consistency. Attempts to tests the accuracy and consistency of the mandibular ramus flexture indicate that the method is not very reliable (e.g., Hill 2000; Kemkes-Grottenthaler et al. 2002).

Various cranial measurements and indices can be used to determine sex but these are known to be population specific (De Villiers 1968a; Meindl et al. 1985).

Size differences

In addition to these morphological methods, is metric analysis (Steyn and İşcan 1999; Loth and İşcan 2000b; Asala 2001). Measurements of various bones are used to develop various formulae (e.g., multiple discriminant functions), which can be used to determine sex especially when the skeletons are fragmentary. These are very population specific (Black III 1978; Macho 1991; İşcan and Miller-Shaivitz; 1984; Meindl et al. 1985; Steyn and İşcan 1997; 1999; Loth and İşcan 2000b; Asala 2001).

Metric analysis employs the use of a few measurements of a single long bone and each measurement is matched with data obtained from South African blacks (e.g., Macho 1991; Steyn and İşcan 1999; Asala 2001; Loth and İşcan 2000b). The femur has been found to a very reliable and most accurate bone to use for sex determination followed by the humerus (Black III 1978; Loth and Henneberg 1996; Steyn and İşcan 1999, Loth and İşcan 2000b). In addition to lengths, diameters and circumferences, indices can be used to determined sex. Metric indices in sex determination are most useful when dealing with fragmentary remains (Kelley 1978; Loth and İşcan 2000b).

This method of sex determination tends to be most useful in determining sexes of bones found in isolation and it was also used to confirm results where morphological methods seemed uncertain or where relevant bones for morphological assessment were either missing or damaged. It is important to bear in mind that size alone is not always a good indicator of sex and can only be used to give tentative results.

3.4 Stature

Stature increases between birth and adolescence. During adulthood, it is relatively unchanging and it decreases towards senility (Brothwell 1981). From the study of twins it has been found that stature is influenced genetically determined and that environmental factors play a small role in influencing an individual's stature. It has been found that stature varies from one individual to the other even if the individuals are from a homogeneous population. However, females tend to have a smaller mean stature than males in most populations (Brothwell 1981).

Estimation of stature from skeletal material is based on the relationship between lengths of bones, especially limb bones, and stature (Sjovold 2000). Estimation of maximum living stature of adults was based on regression equations based on data from South African blacks (Lundy 1983; Lundy and Feldesman 1987). Lengths of long bones of adults were used in combination or individually to estimate stature. Bones used in this study included the humerus, femur and tibia. They were measured using a standard osteometric board and landmarks described in the literature (e.g. Brothwell 1981; Moore-Jansen et al. 1994; Buikstra and Ubelaker 1994). The measurements were taken to the nearest centimeter. Appendix 1 shows various measurements taken on each individual including cranial measurements. Only complete bones of the left side were used but substituted with their right counterparts if the former were missing or incomplete. Incomplete bones were excluded. Stature was estimated for adults only. For each individual, bones with the lowest standard error were selected for stature estimations. To calculate stature, measurements of bone are inserted in to appropriate regression equations (Lundy 1983; Lundy and Feldesman 1987).

3.5 Other observations

Cranial and postcranial measurements (Appendix 1 and 2 respectively) were taken on each individual where possible. The measurements were used for various purposes e.g., for determining sex on some individuals, estimating age of infants and juveniles and assessment of skeletal growth. Data obtained from age estimates of individuals was used to reconstruct the palaeodemography of the study population. Each bone was assessed for lesions associated with pathology and trauma. Teeth were measured and assessed for dental pathology and dental wear. Methods used assess each of these are given in detail at the relevant chapters or sections.