

**SUBADULT GROWTH AND HEALTH FROM OSSUARY SAMPLES  
OF PREHISTORIC SOUTHERN ONTARIO IROQUOIAN  
POPULATIONS**

**by**

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**A thesis submitted in conformity with the requirements  
for the Degree of Doctor of Philosophy,  
Graduate Department of Anthropology, in the  
University of Toronto**

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**Subadult Growth and Health from Ossuary Samples of Prehistoric Southern  
Ontario Iroquoian Populations**

Doctor of Philosophy

1999

Katherine Lynne Gruspier

Department of Anthropology

University of Toronto

**ABSTRACT**

A growth deficit in juveniles, specifically toddlers, has been demonstrated for many prehistoric and historic skeletal samples in North America. All of these samples consist of skeletons with matching dentitions and long bones. This thesis explores the possibility of detecting a growth deficit in four ossuary samples from Southern Ontario where long bones and dentitions are no longer in association.

Each of the four ossuary samples (Fairty, Kleinburg, Carton and Milton) were extensively researched, with regards to their excavation and post-excavation histories, in an attempt to control environmental bias. In one case, radiocarbon dating was done to clarify the date of a sample (Fairty). The results indicate a date much earlier than previously thought, although this date cannot be easily accepted. Potential cultural bias of the samples was addressed by a thorough review of the ethnohistoric documents, and critical appraisal of the demographics of the samples themselves. Much of the research presented here was done in order to minimize potential methodological bias, which has been cited as the most frequent cause of a perceived growth deficit in skeletal samples.

Fairty, a pre-contact, marginal horticultural sample displayed a juvenile growth deficit which was most pronounced in the 1 to 3 year age groups. Kleinburg, a circa-contact maize horticultural sample did not display a longitudinal bone growth deficit in the juveniles, but a cortical bone deficit in both the juveniles and adults of this sample has been shown by the work of others (Saunders and Melbye 1990). The Carton and Milton ossuary samples were biased by human-induced taphonomic changes so severely that no information on growth deficit in juveniles could be derived from them.

The concluding chapter of this thesis provides alternative interpretations of subadult health in Southern Ontario by utilizing the results of this, and previous studies on the same samples. These interpretations are based upon the assumptions that high frequencies of stress related skeletal changes can either be pathological, and therefore indicative of excessive morbidity, or they can be viewed as adaptive, and therefore would not have caused any overt clinical illness. These results are considered to be sample specific.

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# CHAPTER 1

## *Introduction*

A major trend in studies of prehistoric skeletal populations in recent years has been the investigation of skeletal indicators of non-specific stress (see the papers in Cohen and Armelagos 1984, and others). These include dental enamel defects, Harris lines, the presence of cribra orbitalia or porotic hyperostosis, periosteal reactions to inflammation and, the focus of this study, alterations in the growth of the long bones. For the most part, these studies have focused on large skeletal samples, and compared the frequencies of certain indicators amongst samples. More recently, researchers have attempted to refine the methodology necessary for addressing specific questions, such as weaning age and infant death due to acute infection, by including chemical and microscopic studies within their repertoire. While the results have been encouraging, the basic problem is the representativeness of the skeletal sample; Do the dead reflect the living?" Wood et al. (1992) forced researchers to take a good hard look at their samples and the potential for bias and misinterpretation which is inherent within them.

In their extensive overview of potential growth deficits in skeletal populations, Saunders and Hoppa (1993) conclude that methodological problems introduce far too much error into the results of any study of subadult growth. They feel that the error introduced by methodological problems obscures the actual results of any study, such that any biological mortality bias is impossible to discern. Saunders and Hoppa were specifically addressing growth deficit in juvenile skeletal samples, and whether the skeletal (dead) juveniles were shorter than the living (and therefore presumably more healthy) juveniles.

The questions explored in this research stem from my observations over many years of analyzing skeletal remains; and, in particular, the skeletal remains of subadults. In samples from diverse geographical and temporal areas, I have seen that some subadult skeletons can be aged by both diaphyseal length and dental calcification and the results will closely concur. There are individuals within the same samples, however, in whom

the results do not concur, and it is always the diaphyseal ages which lag behind the dental ages. I have always interpreted this as a sign of growth deficit resulting from a morbid state (chronic or acute infectious disease, sometimes exacerbated by inadequate nutrition). In most cases these individuals have been represented by complete skeletons, and there is almost always one or more signs of non-specific stress on the skeletal remains (periosteal reaction, cribra orbitalia and porotic hyperostosis, and dental enamel defects). Generally, the wider the age gap between the dental and diaphyseal result, the more severe and numerous are the signs of non-specific stress.

The skeletal samples analyzed in this research are from ossuaries in Southern Ontario; and, as such, there are no complete individuals. All dental remains are separate from diaphyseal remains. Given this, can a growth deficit be recognized within these skeletal samples? A substantial part of this research is devoted to recognizing and minimizing the potential bias introduced by methodological problems. Saunders and Hoppa (1993) have used the terms; *cultural mortality bias*, and *environmental mortality bias* in defining the two major areas of methodological stumbling blocks which prevent the researcher from adequately addressing the *biological mortality bias*. These terms will be used to discuss the possible problems with the skeletal samples in Chapter 3. Cultural mortality bias refers to any differential mortuary custom practiced by the culture being studied, which may have purposefully excluded individuals from the sample under study. Environmental mortality bias refers to the taphonomic processes which could have affected the remains post-interment. This term will also be used in the discussion of the post-excavation treatment of the samples being studied. Environmental mortality bias (in terms of post-excavation treatment of remains) is the most recurrent reason why samples were not appropriate for inclusion in this study. Both of these types of bias are addressed as major problems by Wood et al. (1992) under their directive that osteologists have a better understanding of the cultural context of their samples.

If it can be demonstrated that diaphyseal growth lags behind dental development when all possible methodological issues are controlled for, a consideration of viable reasons for why this might be so must be addressed. The cautions of Wood et al. (1992) are kept in mind when the results are considered as indicative of morbidity or not. It

must be stated that I am aware that one can never possibly control all potential sources of bias, but I am more optimistic than Wood et al. (1992), that with careful background research, many of these potential problems can be minimized. How, or if, one can translate what is observed on a skeletal sample to what that indicated for the living population who contributed the skeletal sample is a conundrum which may never be solved.

## **Research Objectives**

There is a single primary goal of this research, as well as a number of secondary considerations.

- **Principal Objective:** To determine whether a growth deficit exists in the juveniles of the population samples under study. The methodology being employed has been used for collections of complete individuals, but never for ossuary samples.
  
- **Secondary Aims:**
  1. To investigate possible environmental bias, with an in depth review of the excavation and post-excavation history of the samples.
  
  2. To investigate possible cultural bias by reviewing ethnographic and archaeological evidence pertaining to the period being studied.
    - 3a. To attempt to quantify methodological bias inherent within the samples due to the aging techniques utilized.
  
    - 3b. To identify whether the magnitude of the error introduced by the aging methods used, is less than the differences in ages derived from the teeth and the long bones. If this can be demonstrated, then a true growth deficit is being exhibited by the subadults in the samples.

In essence, I propose to attempt to determine if a growth deficit exists, and if it can be demonstrated in ossuary samples, while addressing the concerns of both Saunders and Hoppa (1993) and Wood et al. (1992) with regards to strict control of cultural context of the remains being studied.

## **Chapter and Appendix Outline**

### ***Chapter 2***

This section outlines the literature pertinent to a study of growth in prehistoric population samples. The review is presented in chronological order to show the evolution of growth studies on past populations. It begins with a review of the early studies in which ages derived from specific samples were published as standards for deriving age from juvenile skeletal remains from other samples. Later studies demonstrate how quantification of growth deficits in juveniles can be used to interpret the general level of health and nutrition in archaeological samples. In most cases, these studies focus on comparing the health of pre- and post-agricultural populations, or pre- and post-contact populations. The most recent literature in the field concentrates on methodological questions such as the testing of standards to derive the most accurate ones, and the testing of potential areas of bias by utilizing samples from historic cemeteries where the age at death of the child was known. Published methods for increasing sample sizes are also included.

### ***Chapter 3***

This section is an in-depth review of the background of the samples utilized in the research. It begins with a summary of Southern Ontario prehistory which covers the periods and stages from which the samples are derived. For each sample the location, date and archaeological information is given. An additional subsection for each sample is devoted to a review of the use of the sample in the years since it was excavated. Notes about missing elements and the storage and preservation of each collection of bones are given. An investigation into the history of each sample is necessary in order to address

its integrity, and the potential for cultural and environmental bias inherent within the sample.

#### ***Chapter 4***

Chapter 4 outlines the methodology of data collection. It includes the specifics of radiographing of the teeth, and measuring of the long bones. Statistical data manipulation techniques and tests are also laid out.

#### ***Chapter 5***

Chapter 5 presents the results of data collection and manipulation on the four ossuary sites analyzed. Each of the samples provides different information, and the analysis follows a different direction for each. The Fairty sample appears to exhibit a growth deficit in the toddler age groups when dental age is compared to diaphyseal age. A sound statistical analysis to demonstrate this could not be modeled, but alternative evidence is offered. The Kleinburg ossuary does not show a growth deficit in the same manner as Fairty, but other analytical techniques have suggested that a growth deficit exists in the toddler age groups as well. Kleinburg also provides an opportunity to analyze interobserver error in utilizing the method of Moorrees et al. (1963a, b). The Carton and Milton ossuaries are excellent examples of environmentally biased samples. Little data could be derived from them, but a database now exists with all dental calcification stages and diaphyseal lengths, should anyone decide to undertake a full analysis of the remains (Note: Milton is being analyzed).

The findings from this study are compared to those of previous researchers who have looked at skeletal indicators of non-specific stress, isotope and elemental analysis, and palaeodemography.

#### ***Chapter 6***

This section summarizes the findings from each skeletal sample, and discusses whether the observed differences in development between teeth and diaphyses can be indicative of a growth deficit. The findings from this research are once again compared

to those of previous studies on the same samples. A reconsideration of burial practices in Southern Ontario during the Late Woodland period is presented, in light of the new radiocarbon dates from the Fairty ossuary. The chapter concludes with another consideration of the contentions of Wood et al.(1992), in light of the findings from the research. Finally, suggestions for areas which would benefit from future research are offered.

### ***Appendix 1***

This is a photocopy of the an article published from the results of early stages of this research: Hoppa, R.D. and K.L. Gruspier (1996) Estimating Diaphyseal Length from Fragmentary Subadult Skeletal Remains: Implications for Palaeodemographic Reconstructions of a Southern Ontario Ossuary. Am. J. Phys. Anthrop. 100:341-354. It is provided for purposes of quick reference.

## CHAPTER 2

### ***A Review of Growth Studies on Dead Population Samples: Evolution of Methodology***

***“Growth processes are the pathways by which variation among adults arises. Therefore, the first step to understanding morphological differences among individuals or populations is to understand the differences in the growth patterns that give rise to the variants being studied” (Johnston and Zimmer 1989:13).***

The following review presents pertinent papers of growth studies on past populations in chronological order. The papers are briefly summarized and important methodological advances are treated in somewhat more detail. Only that information which is directly applicable to this research has been presented; in most cases this takes the form of methodological advances, or findings specific to Southern Ontario prehistoric groups or their cultural and temporal affiliates in North America. Literature which is more specific to other aspects of inferring health from skeletal samples is presented within the discussions of each skeletal sample where it is directly applicable to the findings of this research. A chronological presentation is important in order to stress the evolutionary nature of this area of study. Each paper is, in essence, a reply to the previous one, and an attempt to overcome problems with the methodology presented by the previous paper. The review begins with early studies which present findings from particular skeletal samples as standards to be used by others. The most recent papers contain tests of both methodology and theory as it applies to defining and applying information on normal and abnormal growth patterns in human skeletal samples. Comments are offered throughout the review, and summaries are provided at points where older theories gave way to advances in methodology.

Information pertaining to human growth in past populations has been studied extensively in North America. The first comprehensive growth study was done on the remains from an Archaic collection from Kentucky: Indian Knoll (Johnston 1962). Johnston utilized dental eruption standards and long bone development stages to assign ages to the subadults up to approximately five years of age. Johnston points out that any

interpretations derived from growth studies on skeletal samples from the past must be viewed with caution. He stresses that the dead do not represent the living. The implication is that the least healthy children are more likely to die as children. A later study on the same sample (Sundick 1972, 1978) utilizes dental eruption stages (a modified Schour and Massler 1944 list) to give an age stage for the observed lengths of the long bones in the sample. The results of each study, when compared, exhibit age determinations which are widely disparate for the same individual. Merchant and Ubelaker (1977) note that the differences are likely due to the methodology employed by each researcher, and they attempted to redistribute the ages so that the results were more comparable. Sundick (1978) concludes his study by noting that dental age correlates better with chronological age than skeletal age,<sup>1</sup> and that it does not matter which standards of dental age determination are utilized. Sundick disagrees that the Moorrees et al. (1963a, b) calcification standards are better than the Schour and Massler (1944) eruption ages for large archaeological samples. This is in direct contrast to Merchant and Ubelaker's (1977) caution that the Moorrees et al. (1963a, b) standards are superior. Sundick (1978) summarizes that particular section of his paper by stating that dental standards derived from the same or similar population would be the method of choice. An observation which really does not need to be stated. Another conclusion that Sundick makes is that the articles which he reviewed on growth in living children indicated that there was no difference in height between healthy and sickly children. If true, this would allow researchers to make direct inferences about growth from the skeletal remains of archaeological populations without attempting to ascertain their health status. This is the most contentious issue, as tackled by Wood et al. (1992), and Saunders and Hoppa (1993), and will be discussed in more detail below.

Ubelaker (1974) made the first attempt at demographic reconstruction of ossuary samples using the remains of 319 individuals from two Late Woodland ossuaries in Maryland. He included a critique of age determination methods in his publication. Ubelaker states that the data available at that time for interpreting age from diaphyseal

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<sup>1</sup> The correlation of chronological age more closely with dental age than skeletal age in children was first noted by Garn et al. (1958) in their extensive longitudinal growth study of living children.

length was largely inappropriate. The Indian Knoll standards provide ages only up to approximately five years, and the extant cross-sectional growth studies were derived from modern White (and therefore non-comparable) samples. Further, the White standards utilize radiographs of long bones from living children as opposed to the dry bones themselves. Ubelaker (1974) utilizes Stewart's (1954) standards which derived from a small number of skeletal remains of an Inuit sample. One of the publications which Ubelaker eschewed was that of Maresh (1955) (a radiographic study on living Caucasian children from the United States). Stewart (1979) states that he aged the "few" Eskimo skeletons for his 1954 study by dental eruption. He also notes that they appear to be less comparable to the later published Arikara curves (Merchant 1973) than the growth curves derived from the data of Maresh (1955). This is in spite of the fact that there is potential error introduced by the fact that the "chubbier" children's bones were further away from the x-ray cassette than those of thinner children, and that certain areas of the skeleton, by virtue of their being in closer proximity to the skin (e.g. the distal radius) would be less distorted than those areas deeper within tissue (Maresh 1955). In essence, the "White" standards of the Maresh sample are more useful for determining age at death from diaphyseal length for the Arikara than those derived from the Inuit. It is presumed then, that the standards of Maresh would have been more useful for deriving ages from the Maryland ossuary samples. Ubelaker (1989) interprets these differences as illustrative of the growth rates of each group, the Indians being slower than Whites and faster than Eskimos. The timing of the growth rates concur with the final adult statures of each group. It may also be that Stewart's (1954) Inuit sample was too small to include enough variation.

Ubelaker (1974) provides an in-depth discussion of the then available standards for the determination of age at death from both dental eruption, and dental calcification. He notes that the Schour and Massler (1944) eruption standards are flawed, in that they derive from a sample of only 30 children, many of whom were ill. In 1987, Ubelaker further clarified the origin of the Schour and Massler data by stating that it was derived from the 1933 study by Logan and Kronfield on 25 diseased children, sexes combined, between birth and 15 years. Merchant (1973) notes that there are differences in the charts published in 1941 and 1944, which could lead to a difference in age determination of as

much as 2 years. Ubelaker (1974) states that many studies have shown that dental calcification is less affected by diet and dental disease. More importantly, Ubelaker cites a number of studies (Steggerda and Hill 1942, Hurme 1948, Garn and Moorrees 1951, Dahlberg and Menegaz-Bock 1958 and Hrdlicka 1908) which suggest that the *eruption* of the posterior teeth occurs slightly earlier in non-White populations. Ubelaker aged all of the subadult dentition from the two ossuaries by both the Schour and Massler (1944) and the Moorrees et al. (1963a, b) standards. He found that the ages derived from the dental eruption standards were consistently higher than those derived from the calcification standards. Finally, Ubelaker compared the ages derived from dental calcification, dental eruption, and diaphyseal length of the femora for each sample. The dental calcification and diaphyseal length curves compare well with each other, while the dental eruption curve deviates from both. In most cases the sample size is around 50 individuals. Ubelaker makes the important observation that the method for deriving age from diaphyseal length is biased because the ages of the sample are derived from dental eruption standards. Dental eruption timing is more variable than dental calcification stage attainment, therefore, utilizing the Stewart (1954) diaphyseal age standards based on dental eruption introduced error in diaphyseal age determination from the beginning. The ages utilized for his palaeodemographic reconstruction were taken from the femoral lengths in the end simply because more individuals were represented by measurable femora, than by dentition.

Building on the work of Merchant (1973), Merchant and Ubelaker (1977) published an analysis of the growth of the protohistoric Arikara, with comparisons to other published samples. The point of the study was to first, compare the ages derived by the Moorrees, et al. (1963a, b) dental standards to the Schour and Massler (1944) standards for the sample (as Ubelaker 1974 had done with the Maryland ossuary samples), and second, to compare growth curves amongst a number of skeletal samples. The summary growth data is presented in graphical form for modern Whites (Maresh 1955), Protohistoric Arikara (aged by both the Schour and Massler 1944, and Moorrees et al. 1963a, b standards), Archaic Indian Knoll (both Johnston 1962 and Sundick 1972), Late Woodland Indian from Illinois (Walker 1969) and recent Inuit (Stewart 1968). Merchant and Ubelaker again found that the Schour and Massler (1944) standards tended

to overage the individuals in comparison to the Moorrees et al. (1963 a, b) standards. Merchant and Ubelaker overcame the problem of not being able to determine sex of the individuals by combining the male and female means presented by Moorrees et al. (1963a, b). The Schour and Massler (1944) standards are not presented by sex. They also note that in some of the graphs, the difference between the two growth curves for Indian Knoll (Sundick 1972 and Johnston 1962) is greater than that between Indian Knoll and the Arikara. They state that when compensation for methodological variability is made (they give no specifics), the growth curves for the Arikara and Indian Knoll remains are almost identical. This appears to be true despite the fact that they are separated by 4,000 years, practiced different subsistence modes, and are geographically dissimilar. The graphs of long bone development by age are presented for use by the researcher who has no dental remains with which to age a subadult skeleton. The authors stress that past 11.5 years, the Arikara data are not useful due to the small sample size. They conclude with the point that the deciduous second molar calcifies earlier in Blacks than in Whites (Gilster et al. 1964), and that this *could* occur in Indian and Eskimo teeth.

These early studies present attempts at constructing growth curves from skeletal samples. All are published as “standards” to be used to derive ages from ethnically similar skeletal samples of individuals of unknown age. They concur that dental aging is more accurate than diaphyseal aging, but in the absence of dental remains, their growth curves would be useful. All of the researchers note that biological mortality biases likely existed in their samples, but generally believe that it is an issue which can not be addressed. Sundick (1978) went so far as to review a number of studies on living children in order to assess whether morbidity affected growth. He is adamant in his conclusions that no evidence could be found to support the supposition that the dead of an archaeological sample may well not reflect the living in terms of growth and adult stature.

Cook (1981), expanding upon her earlier work studying rates of stress indicators (1976, 1979) in Woodland and Mississippian samples from West Central Illinois did a thorough literature search, and concluded that morbidity did have an effect on growth. These studies were derived from modern reference populations in the New World.

Buikstra and Cook (1980) in a general review, stated that comparisons between the growth curves of skeletal samples, in particular the comparison of archaeological with modern White samples, should be done cautiously. They cite the problems with the determination of age at death of the remains, and stress that prehistoric data are cross-sectional as opposed to longitudinal. They reiterate that a number of stressors can permanently affect growth and dimensions of long bones. It should be noted that Cook and Buikstra (1979) aged their skeletal sample by comparison of dental development to the Schour and Massler (1944) standards. Buikstra and Cook (1980) were among the first to study a collection of non-specific indicators of stress on skeletal samples. Studies by Lallo (1973), Lallo et al. (1977), Lallo et al (1978), Lallo et al. (1980) and Mensforth et al. (1978) were contemporary, and focused in the same manner. This focus became the prime interest of palaeopathologists throughout the 1980s.

Although long bone growth by length is the focus of this study, it is directly associated with the width of the long bones, and in particular with percent cortical area. Cook had looked at this in her 1979 study, and concluded that osteoporosis in juveniles was likely linked to dietary deficiencies. Pfeiffer and King (1983) did an analysis of the Kleinburg and Uxbridge ossuaries, measuring the cortical areas of the femora, second left metacarpals and fifth lumbar vertebrae. They calculated their results using both the Barnett and Nordin (1960) osteoporosis scores, and the Garn (1970) percent cortical area calculations. The results show high percentages of osteoporotic individuals, those in which cortical bone remodeling appears to be highly deficient (as compared to modern British individuals over 50 years of age). The authors also state that both ossuaries have a large number of young adult individuals, with males being well-represented, so this is not an age or sex bias. In an attempt to explain this, Pfeiffer and King (1983) suggest that a number of factors could have contributed to the low percent cortical area, such as; low calcium intake, excess phosphorus relative to the calcium, and protein-calorie malnutrition. The assumptions that these dietary deficiencies existed are based upon the reconstruction of the Huron diet by Heidenreich (1971) ( a corn horticultural subsistence base). Pfeiffer and King state that there is really no evidence to support a biomechanical or genetic hypothesis. Their reasoning for lack of a biomechanical cause seems acceptable: that there is “no reason to believe that the Iroquoian horticulturalists were

markedly inactive” (1983:27). Finally, the authors recognize that studies on living children have shown that protein-calorie malnutrition may result in low percent cortical areas (Garn et al. 1964, 1969), and that this has been used to address palaeonutrition in skeletal populations (Cook 1979). They state that they “know of no evidence, however, that such childhood cortical deficiencies are normally retained into adulthood” (Pfeiffer and King 1983:27).

In 1984, a collection of papers was published by Cohen and Armelagos. The emphasis of the collected studies was to define health in pre- and post-agricultural skeletal samples throughout the world. Although each study differed somewhat, they were generally confined to compare rates of stress indicators, including diaphyseal length and width in subadults. A large part of the impetus for these studies had come from the growing body of research on growth and health in disadvantaged living children (Frisancho 1978, Garn et al. 1964, Scrimshaw 1975, Scrimshaw et al. 1959, and others ). In Cook’s (1984) contribution from the same Illinois samples as previously referenced, she begins the section on growth and development by stating;

“Bone growth and development is mirrored in juvenile height for age, stature, bone proportions, and sexual dimorphism in adults, cortical bone maintenance, and growth arrest indicators. All of these sources may be used to study nutritional status in the living, and they provide the first line of evidence in past populations. Interpretations of these sources of information is a complicated issue, however, for all reflect influences apart from nutrition. For example, population-specific genetic factors, heterosis, and disease load affect both skeletal growth and final adult stature, even though nutrition plays an important role in both. Similarly, disease load and mortality levels are reflected in stress indicator frequencies and bone maintenance. These interactions complicate the interpretation of data on growth and development derived from prehistoric skeletons, but the interactions themselves provide a useful perspective on health and adaptation (Cook 1984:237).

Cook (1984) concedes that biological mortality bias exists, but feels that the dead give a unique view of natural selection, and may provide better information on the biological meaning of subsistence than surviving individuals would. Cook and others in this volume (Cohen and Armelagos 1984) were taking the view that nutrition is the primary factor causing stress indicators on skeletal remains. The current mode of

thinking is that it was not nutritional deficiency alone which “stressed” pre-modern populations. Cook took a unique approach to this particular study, in that she analyzed only those individuals less than 6 years of age in order to minimize sample size problems, and statistically test differences in growth rates between samples. She also states that height differences between the sexes are small for those ages, and children under six years of age are more sensitive to nutritional insults. Using the age determinations for the samples previously published (it appears that the Schour and Massler charts were used, although this is not made explicit), the age was plotted against diaphyseal length for each individual. She applied a regression equation in order to give the data a linear fit, which compared the log of the conception corrected dental age with the length of the diaphyses of individuals. The data from each site were compared with T-tests to detect differences in slope. Utilizing this Promethean approach allowed Cook to contrast samples which were more comparable, and she discovered that there was a definite difference in femur length by temporal interval. The Late Woodland series (containing those individuals whom it is hypothesized had begun to exploit agriculture as a subsistence base) have shorter femora for their age than individuals temporally preceding and following them. She states that individuals who are short for their age also exhibit higher frequencies of other stress markers, and that the inference that nutritional deficiencies are responsible for growth retardation is clear.

An extensive study of the skeletal remains from Dickson Mounds (Central Illinois Valley), a multi-component, pre-contact site (AD 950-1300) is presented in the same volume (Goodman et al. 1984). The subadult remains between 0 to 15 years were aged by dental eruption as compared to Schour and Massler (1944), and epiphyseal closure (Krogman 1962), vertebral fusion (Anderson 1962) and appearance of ossification centers (Krogman 1962). It must be noted, that for the bulk of the youngest individuals, this means that they were aged solely by dental eruption. Distance curves for the length and circumference of the tibia are re-presented from Lallo (1973). While on average the Middle Mississippian diaphyses are longer at birth, there is a slowing of both longitudinal and circumferential growth between the 2 to 5 year cohorts from the sample during this period of increased sedentism, agricultural subsistence, and trade. The researchers ran a series of analyses of variance (ANOVAs) between temporally different samples for each

age cohort. They found that the only age group which showed statistically significant differences were the 5 to 10 year olds. The 2 to 5 year olds were not significantly different. The graphs in the publication do show that the growth deficit observed between the Middle Mississippian and earlier Late Woodland and Mississippian Acculturated Late Woodland juveniles began between 2 to 5 years of age. This indicates that stress was most severe in this age cohort. Further evidence for a decrease in growth velocity arose from attempts by Goodman (1980 cited in Goodman et al. 1984) to fit tibial length against dentally aged individuals from birth to 7 years. He found that a third order polynomial model gave a significantly better fit to the data than a simple second degree linear model, and states that this is likely due to the decrease in observed length over that predicted by the linear model for individuals between 1.5 and 3 years.

The first of a collection of papers by Jantz and Owsley on the growth of a large sample of Arikara skeletons appeared in 1983. It dealt specifically with timing differences in the calcification of the permanent dentition between Modern Whites and Arikara samples. The authors scored the dental calcification stages of extant maxillary incisors and all mandibular teeth after the standards of Moorrees et al. (1963b). The authors re-scored a number of teeth, and found that their results were consistent. They pooled the ages by sex, since sex cannot be determined in subadult skeletons, and note that this source of error should not radically affect their results. Utilizing the first and second premolar as reference points, they compared the age results from each tooth to them, and tested the mean differences by paired samples T-tests. The results are of use for further discussions about the results of this study, and are reproduced in Table 1 below.

Pair (A-B)	N	Difference (years) X	t
I <sup>1</sup> -P <sub>1</sub>	100	0.77	10.65***
I <sup>1</sup> -P <sub>2</sub>	90	0.52	6.13***
I <sup>2</sup> -P <sub>1</sub>	95	1.08	12.84***
I <sup>2</sup> -P <sub>2</sub>	88	0.79	8.87***
I <sub>1</sub> -P <sub>1</sub>	68	-0.12	-1.67 <sup>ns</sup>
I <sub>1</sub> -P <sub>2</sub>	68	-0.25	-3.38**
I <sub>2</sub> -P <sub>1</sub>	70	0.24	2.85**
I <sub>2</sub> -P <sub>2</sub>	71	0.06	0.80 <sup>ns</sup>
C-P <sub>1</sub>	188	-0.24	-4.20***
C-P <sub>2</sub>	159	-0.55	-7.84***
P <sub>1</sub> -P <sub>2</sub>	166	-0.17	-3.29**
P <sub>1</sub> -M <sub>1</sub>	153	0.27	4.84***
P <sub>2</sub> -M <sub>1</sub>	118	0.51	8.41***
P <sub>1</sub> -M <sub>2</sub>	161	-0.81	-13.37***
P <sub>2</sub> -M <sub>2</sub>	171	-0.55	-9.08***
P <sub>1</sub> -M <sub>3</sub>	53	-2.30	-17.10***
P <sub>2</sub> -M <sub>3</sub>	65	-2.00	-16.67***
M <sub>1</sub> -M <sub>2</sub>	116	-1.11	-15.88***
M <sub>2</sub> -M <sub>3</sub>	75	-1.52	-15.13***

\* P < 0.05

\*\* P < 0.01

\*\*\* P < 0.001

<sup>ns</sup> Not Significant

Table 1: Tooth pair contrasts, mean differences and paired T-values for maxillary incisors and mandibular teeth of the Arikara (drawn from Owsley and Jantz 1983:469).

As can be seen above, even though most of the differences were statistically significant, the actual difference in years is rather insignificant. The important differences are seen with the maxillary incisors, mandibular second molars and mandibular third molars, which gave higher mean ages than the premolars, and the mandibular canines which gave younger ages than the premolars. Of these, the maxillary incisors and the mandibular third molars assigned ages a year to two older than the premolars. The authors decided to base their age determinations for future growth studies

primarily on the mandibular premolar, with selected subsets of teeth chosen by availability and performance for age determination. Jantz and Owsley's following publications (1984 a, b) utilize seven samples of historic Arikara remains, aged by the above modified dental calcification method. As Cook (1984) had done, they produced growth curves by linear regression in order to make the data between sites more comparable for inter-site testing. They found that the most recent sample of Arikara remains (AD 1835) experienced the most growth deficit for most of the bones measured. It was this period during which the Arikara experienced the most "stress". Owsley and Jantz (1985) looked specifically at the perinatal femora of the seven Arikara samples. They determined that the later sites (AD 1760-1835) produced more smaller sized infants, or more preterm births or small-for-gestational-age babies than the earlier sites. This, they state, is an indication of increased environmental stress in the later Arikara cultural period.

Saunders and Spence (1986) did a similar study to determine the "birth size" of children from Southern Ontario Iroquoian populations. They identify this as a necessity since the standards of Merchant and Ubelaker (1977) do not provide refined ages, simply presenting perinatal infants as being aged 0 to 6 months. Their sample consisted of 40 individual infant burials dating from AD 1350 to 1641 (Middle and Late Ontario Iroquoian cultures). These individuals had all derived from habitation sites, and were not derived from ossuaries. The individuals were placed into stages using the dental standards of Kraus and Jordan (1965) and Moorrees et al. (1963a), applied to one half of a mandible and maxilla. The researchers then compared the sequential order to the derived chronological ages from Moorrees et al. (1963a). They found that the correlation was good (Spearman's  $r = .899$ ,  $p = .005$ ), but the chronological age estimates did not agree with those individuals who had later developing molars as compared to the anterior teeth, or in cases where some teeth were missing. They then measured all of the diaphyses. The measurements were ranked against the dental ages, and it was found that there was a very good correlation between dental age and diaphyseal length (humerus; Spearman's  $r = .968$ , femur; Spearman's  $r = .904$   $p = .005$ ). It follows that relationship is seen between the two, if dental development advances with age as bones grow longer with age. The researchers state that the diaphyseal lengths by age cohort are similar to

those presented by Merchant and Ubelaker (1977), but the mean bone lengths from this sample are shorter in the birth to 6 months cohort. The sample under study shows a concentration at a certain bone length (60-70 mm for the humerus). Aged by different methods, this concentration shows up as a prebirth sample by the Kraus and Jordan dental method (36 to 38 weeks), a cluster at 2 months of age by the Moorrees et al. dental standards, a cluster between birth and 6 months for the Merchant and Ubelaker (1977) diaphyseal standards, and a cluster at birth using the data of Scheuer et al. (1980). This same cluster compared well to Stewart's (1979) calculation of birth-size concentration from the Arikara studied by Merchant and Ubelaker (1977). The authors point out that the Moorrees et al. (1963a) deciduous dentition aging standards were derived from the most variable posterior teeth (canine and first and second deciduous molars), and that data collection for these teeth began when the individuals were 3 months of age. The bias inherent in the reference sample is likely causing the birth group of infants to appear two months older. The high  $r$  values between the dental ages and the diaphyseal ages is reassuring as it suggests that the actual methods used to derive the ages complement one another, despite the fact that they are derived from different reference populations. A point that Saunders and Spence fail to make, and in fact that no researcher has made, is that the diaphyseal growth standards presented by Merchant and Ubelaker are based upon the dental ages as derived by the standards of Moorrees et al. (1963a, b). This is bound to make the results more comparable since one is comparing derived ages to a dental method, and then a diaphyseal method which is derived from the same dental methods. Saunders and Spence conclude that the ability to separate fetal deaths from neonatal and post-neonatal deaths have implications for reconstructing cultural and mortuary patterns. This is particularly useful with Southern Ontario sites, as the hypothesis that infants were buried elsewhere, and not in the communal burial pit is often cited. Determining whether peri-natal remains found in ossuaries are those of infants or fetuses will help the investigator assess whether a skeletal sample is complete or lacking certain individuals due to cultural practices.

Mensforth (1985) compared a sample of Archaic remains (Bt-5) with that of a Late Woodland (Libben) sample. He calculated growth rates of the tibiae from skeletons aged by dental development (his method is not made explicit in the paper), and found that

the Late Woodland sample (sedentary horticulturalists) lagged in growth, specifically between 6 months and 4 years of age. This lag was attributed to both nutritional deficiency and disease. Mensforth also records a high incidence of periostitis in the subadults of the Late Woodland sample.

During the 1980s, the focus of growth studies of past skeletal populations changed. No longer were growth curves published as age determination tools for any and all skeletal samples. The point was to produce curves which could be compared with other sites across time. A skeletal sample that lagged behind another in growth was considered to have been stressed. At first this was thought to be solely the result of nutritional deficiency. Later, as studies on living populations were taken into account, the synergistic effects of both malnutrition and infectious diseases were discussed, along with factors of stress produced by living within the environment of an over-crowded village. Some important methodological steps were made during this time. The evidence mounted enough to convince most researchers that the Schour and Massler charts for dental eruption were flawed. The most widely accepted standard for dental aging became the dental calcification method of Moorrees et al. (1963a, b). One pair of researchers (Owsley and Jantz 1983) tested inter-tooth variation for age determination within their samples, and modified their choice of teeth for age determination. They include only those that did not provide widely divergent ages from the others. Finally, linear transformations were applied to the growth curves of samples in order to compare them more effectively.

In 1989, a review of growth studies on skeletal samples was published (Johnston and Zimmer). The authors give a brief review of the problems with determining age at death from unknown skeletal remains, and address issues of methodology and design. They review the growth studies to date on skeletal samples (see this reference for studies on skeletal samples outside of North America). The main emphasis of the review is the use of growth studies as an indicator of the overall health of the population. It is the contention of the authors that growth studies are sensitive indicators of the environment. They summarize the studies to date as all suggesting that the stresses are high at the introduction of agriculture and the concomitant problems of sedentism, crowding,

sanitation and disease transmission are well-illustrated by the growth deficiencies seen among post-agricultural populations.

Lovejoy et al. (1990), following on the work of Mensforth (1985), utilizes regression analysis to smooth their data on long bone lengths of the Libben population. They first critically analyze the determination of age through dental calcification of the skeletons, by comparing data on emergence through the gum (eruption) between modern White children and modern Amerindian children. They found that eruption of the tooth through the gingiva is advanced in Amerindian samples, and that this increases with age. This had been noted by other researchers. They calculate an average discrepancy between the two populations in years (0.69), and apply it to a sliding scale of twelve years to produce a correction factor of 0.0575 years of delay per year added to the mean calcification age for the individuals in the Libben sample. They then compare the diaphyseal lengths of the prehistoric Libben sample to modern children of European origin. They found the same growth deficit between 6 months and 4 years as Mensforth had (1985). The Libben people were transitional agriculturalists, and apparently had a nutritionally adequate diet. Lovejoy and colleagues conclude that the growth lag is due solely to disease. They indicate the high frequencies of periosteal reactions as noted by Mensforth (1985) as validating their claim. Most importantly, Lovejoy and colleagues propose that the subadult deaths were most likely due to acute conditions which would not have affected the dental or osseous development rates in this sample. One observation does not appear to necessarily follow from the other, as periosteal reactions suggest that the body had time to mount a reaction to an infection, thereby making them indicative of chronic conditions. What the researchers were trying to say (one surmises), is that there is increased evidence for infection in the population as a whole (by periosteal reactions), thereby suggesting an overall increase in disease. The children would then be susceptible to many more acute-type childhood infections which would increase their probability of dying. The theory was that the diet was nutritionally adequate, so this cannot be causing the observed growth deficit. It is simply not clear what was causing the growth deficit. The important point is that Lovejoy and co-workers are concluding that there should be no biological mortality bias in their sample because acute infectious diseases are responsible for most of the juvenile deaths.

Saunders and Melbye (1990) looked at subadult mortality and skeletal indicators of health in the Kleinburg (AD 1580-1600) and Ossossané (AD 1636, May 13) skeletal samples by comparison of diaphyseal length ages (after Merchant and Ubelaker 1977) from different bones with dental calcification ages (after Moorrees et al. 1963a, b) and by assessing cortical bone volume. They found that the individuals aged by dentition and radii had a peak mortality rate at 2 to 3 years of age. The femoral diaphyses were also aged, but there was actually a lack of individuals in the 2 to 3 year group. This was due to a lack of measurable femora. There were only 55 femora as compared to 78 radii and 147 mandibles from children aged 0 to 15 years. The Ossossané sample had the highest proportion of dead in the 0 to 1 year category, with the second highest in the 2 to 3 year category. It should be noted that the long bones were, for the most part, not measurable due to breakage and erosion. The authors suggest that the peak of mortality in the 2 to 3 year age category coincides with the high weaning age mortality occurring at 2 to 3 years which has been suggested for prehistoric societies (Clarke 1977), and for the Huron Iroquois from ethnohistoric information (Englebrecht 1987). In addition, when percent cortical area was plotted against total area for the femora and radii of the Kleinburg sample, areas of dispersion were noted between 1 and 4 years of age for the femora, and between 2 and 4 years of age and again between 7 and 11 years of age for the radii. Not only did percent cortical area drop, but the absolute parameters (total area, cortical area and medullary area) were reduced as well. These differences were significant when analysis of variance and the Kruskal-Wallis test were applied to them.

Saunders and Melbye (1990) suggest that the lower percent cortical area for toddlers reflects the susceptibility of the children to chronic nutritional stress and infectious disease associated with weaning. However, ethnohistoric research has suggested that the diet of the Huron was nutritionally varied (Schwarz et al. 1985). The authors then state that this may be a normal response (thinner cortical bone), or it may reflect cultural practices with regards to the specific foods fed to children. The authors remind the reader of the study of Pfeiffer and King (1983) which found the adults of the Kleinburg sample to suffer from reduced bone density. In conclusion, the authors state that Iroquoians were probably not nutritionally stressed, but it may have been other cultural and demographic changes occurring around contact which caused the cortical

bone loss and this continued into adulthood. This paper is utilized for its comparative information in the results section of this study.

In 1992, another review article on the analysis of subadult skeletons and growth related studies appeared (Saunders 1992). The contribution first discusses the problems with sampling, age determination and sex determination. It then focuses on a review of growth studies of skeletal samples, and gives recommendations for future research. Saunders reviews the literature pertaining to sampling problems with archaeological material, and suggests that “factors such as differential burial practices and inexperience on the part of the excavators can prove more important to subadult skeletal preservation than differential tissue survival” (Saunders 1992:2). It has been the experience of this researcher that no matter how delicate or poorly preserved the remains of an infant, a seasoned excavator can retrieve enough of the skeleton to allow for a basic skeletal analysis, in almost all cases. The potential problems with cultural bias for this study will be presented in the concluding chapter. Saunders reviews published methods for sex determination of subadults (because age determination standards are often presented by sex), and concludes that no method works very well. Obviously, methodology needs to be derived and tested, and she suggests forensic cases and historic cemetery samples, where age and sex of the decedents is known, should be used to refine existing techniques and devise new ones. Age determination, although more accurate in subadults than adults, remains a problem due to our inability to sex the remains. There is an additional problem with determining true chronological age from physiological (or developmental) age because of both individual variation and environmental effects on the growth process. She states that dental calcification is the best method for determining age at death (see also Ubelaker 1987, 1989) since it is independent of skeletal maturity and closely approximates chronological age. Further, it can be used from prenatal ages through adulthood. The limitations of the present systems are discussed, mostly focusing on the fact that they are derived from healthy White children. Saunders critiques the efforts of Lovejoy and co-workers (1990) in attempting to modify calcification rates for the Libben sample based on eruption differences between Whites and Amerindians. She states that dental development is not highly correlated with dental eruption which can be modified by premature tooth loss. This is a real problem in archaeological samples where the

caries rate and concomitant loss of teeth due to caries is high. Saunders reviews Trodden's (1982) study of dental calcification from radiographs of living Indian and Inuit children. Trodden found slightly lower dental calcification ages for Inuit and Indian when compared to Whites in selected teeth, when using the standards of Moorrees et al. (1963b). The total delay amounts to 0.0191 years of lag in calcification per year. This is very slight. Saunders cautions that Trodden had a small samples size.<sup>2</sup> It should also be noted that her study was cross-sectional. Saunders then discusses the pros and cons of various dental calcification standards (Demirjian 1978, Demirjian and Goldstein 1976, Kraus and Jordan 1965, Moorrees et al. 1963a, b). The negative aspects of all the methods are that they are population specific, and that they require the calculation of a mean age by combining the means for both sexes.

In regards to age determination by epiphyseal ossification and fusion or diaphyseal length, Saunders states that "it is well known that there is considerably more potential for variability in skeletal age in comparison with dental age because of the stronger environmental influences on the developing long bones" (Saunders 1992:11). She briefly reviews some of the limited sources for determining age by epiphyseal union in the pre-pubertal subadult skeleton. Growth studies utilize diaphyseal lengths in concert with dental ages. The dental ages act as a close approximation to the chronological age of the individuals, while the skeletal age functions as an indicator of growth defects. Saunders states that it is important to utilize standards which are racially similar to the samples being studied. Saunders gives an overview of growth studies on archaeological populations to date, many of which are reviewed above. She begins by presenting the contrasting information on whether skeletal samples are biased, or if they are a true representation of the living population. She states that it is difficult to assess some of the earlier studies (e.g. Johnston 1962, Lallo 1973 and others on non-North American samples), since they utilize dental eruption, or a combination of methods to determine age at death of the skeletons. She then reviews some of the more methodologically important papers, as reviewed above (e.g. Cook 1984, Jantz and

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<sup>2</sup> The actual number of individuals in the study was; 68 Inuit males, 81 Inuit females, 108 Indian males, and 128 Indian females.

Owsley 1984 a, b, Lovejoy et al. 1990, Merchant and Ubelaker 1977). A very important point to this section is that longitudinal growth studies on living children can assess individual variation, the timing of significant growth events, and the relative growth velocities. Skeletal “growth curves” are extracted from a cross-sectional sample of the dead. Saunders states that these are not in reality growth curves at all, and that plotting the relative increase in diaphyseal size by dental age group is an estimate of velocity changes in bone size, not true velocity curves as would be calculated from living individuals. These limitations were suggested by Johnston and Zimmer (1989) also, but not as directly. The only real issue that can be addressed is that of the health of the community, or the adaptation of the population to its environment. She concludes the section with examples of how growth studies have been interpreted. These have been discussed above. Saunders concludes her contribution with suggestions for future research which include the comments about sex determination presented above, an expansion of dental development studies into other living populations (which would be cross-sectional in nature), and utilization of other dental calcification standards. Growth related research must continue on forensic cases and historical cemetery samples, where the identity and true age of the individuals are known.

Although relatively few “growth studies” on skeletal samples had been published, methodological refinements and interpretations of the data had advanced swiftly to this point. Johnston (1962) has cautioned that these studies looked at dead individuals, and there was a good chance that they did not reflect the living. It would seem that most researchers were circumspect in their interpretations, and kept this in mind.

In 1992, a paper appeared that challenged all of these interpretations. Wood et al. published “The Osteological Paradox”, dealing specifically with the potential problems with inferring health from skeletal samples. They listed three problem areas: demographic nonstationarity, selective mortality and hidden heterogeneity in risks. They discussed the latter two in detail, and this review is most concerned with their comments on selective mortality. Wood et al.(1992) contend that any age cohort of a skeletal sample will be biased towards exhibiting lesions (or in this case growth deficits) which are most common during that age cohort, regardless of the lack of cultural or

environmental mortality bias. They state that clinical data concerning population prevalence of disease is similarly affected, as the sample is biased towards those individuals who are ill. In both of these cases, the observed frequency of pathological lesions will overestimate the true prevalence of the disease within the entire population, and larger sample sizes will not alleviate the problem because one would just have more ill individuals. This is not a new idea, Johnston voiced it 30 years previously (Johnston 1962). This overestimation will not be balanced out by the fact that a small percentage of affected individuals will actually show evidence of a pathology in the form of a lesion because the relative weights of both of these factors cannot be quantified. *Hidden heterogeneity of risk* is a real problem which even demographers cannot address. Basically, skeletal samples are composed of individuals who varied in their underlying *frailty*, or susceptibility to disease or death, be it from genetic causes, socioeconomic differences, microenvironmental variation or temporal trends in health. This *frailty* or susceptibility cannot be quantified; therefore, "it is impossible to interpret aggregate-level age-specific mortality rates in terms of individual risks of death" (Wood et al. 1992:345). The problem of non-quantifiable *frailty*, states Wood et al., makes it impossible to obtain direct estimates of demographic or morbidity rates from archaeological samples, and forces the researcher to infer health in the past from aggregate or population level statistics, even though *frailty* is an individual biological characteristic.

Of particular interest to this study is the example given by Wood et al. (1992) concerning the use of short stature in juveniles to interpret stress in living populations. They state that alternative views may be proposed if one keeps in mind that the skeletons represent individuals who have been subject to selective mortality acting on *heterogeneous frailty*. They give the example of a sample of 5 year olds from two groups which are experiencing no stress related stunting, but that children who are short for their age are at a higher risk of death. They propose, then, that when mortality is high a larger portion of the entire population is represented by the dead, including those of average and above-average height. This results in a sample of relatively tall dead subadults. If there is a period of low mortality, then only the shortest, most frail individuals will contribute to the dead sample. Basically, they state that the appearance of a growth deficit is

uninformative about either stature or health of a population when the level of mortality, and the relationship between stature and *frailty* are unknown. The level of mortality cannot be known from archaeological populations unless sound documentation exists. All of the studies noted above generally assume that there is a relationship between short stature and risk of death, as has been shown on numerous studies of living populations (Bairagi et al. 1985, Chen et al. 1980, Fogel 1986, Heywood 1982, VanLerberghe 1988).

Wood et al. (1992) do provide some hope for future studies concerning this specific problem, and the other problems discussed in the paper. They state that most of the methodological problems with archaeological material (basically cultural and environmental mortality bias and the problems with differential diagnosis of lesion-producing diseases), can be alleviated by more archaeological excavations with better controls and tighter interpretations. The theoretical problems discussed in the paper are more difficult to approach. Four suggestions are offered: borrow work from epidemiologists on sources of heterogeneity in frailty, and how it is expressed in living populations; understand how specific frailty distributions compare to the distribution of risk of death of individuals in a population; address the pathological process of each disease in a more specific manner; understand the effects of the culture of the population in determining heterogeneous frailty and selective mortality.

I feel that these “simple” problems cannot be readily addressed, because we will not be able to excavate more samples of North American Native remains at least, not in the near future, and likely never. Additionally, current excavations of skeletal samples are generally salvage operations which are not problem oriented. Information derived from these excavations may be biased. This is a thought-provoking contribution to the literature, but some concerns raised within it have only a remote chance of being addressed. Individual frailty can never be known from dead individuals. A look at any recent epidemiological study (e.g. studies on contributing factors to breast cancer) reminds us that this cannot even be approached in the living, as one can never define all of the contributing factors, and it is never a simple cause-and-effect relationship. This contribution does, however, compel researchers to present alternative hypothesis, and

provides basic material for doing so. The Osteological Paradox is discussed further in Chapter 6.

In 1993 Saunders, DeVito, Herring, Southern and Hoppa published a paper which attempted to test one of the methodological problems with determining age at death from subadult skeletal remains. While this research was undertaken on a European historic cemetery sample from Belleville, Ontario (AD 1821-1874), the findings are important for this study, as they contribute to the methodology chosen to determine age at death from the dental remains for this analysis. Dental radiographs were taken from the remains of the children in the sample with known age and sex. Calcification stage was scored after Moorrees et al. (1963b). Mean age at death was calculated from the charts provided by Moorrees et al. (1963a, b). Mesial and distal root stage ages were averaged for the molars after a test with the data found no significant difference in the degree of calcification for the two roots by tooth. All scores but apex complete were used to determine age at death. Apex complete is the final stage of development which a tooth can exhibit. An age of attainment for this stage is provided by Moorrees et al. (1963a, b), but the individual could have been that age or older at death. All present and observable teeth from each individual were scored. The researchers also assigned each permanent tooth an age derived from the Anderson et al. (1976) dental calcification study. A mean age at death was produced for each individual by averaging the ages provided by each tooth with sexes pooled. The researchers then had a database with three separate “mean age of attainments” assigned to each individual, one derived from the deciduous teeth (Moorrees et al. 1963a), and two each from the permanent teeth (Moorrees et al. 1963b, Anderson et al. 1976). The researchers then combined some of the results for testing, as follows: the two permanent tooth standards, all three standards, and finally, only the results from the combined Moorrees et al. standards. Individual age estimates and the combinations listed above were compared, both on a case by case and complete sample basis, to the skeletons of known age at death. Within individual coefficients of variation were calculated for each individual to test the variation of each tooth. An overall age at death curve was compared to the expected age at death for the entire cemetery population as obtained from the parish records. An important methodological test was undertaken by deriving the “age of prediction” from the “age of attainment” tables of Moorrees et al.

(1963a, b). This involves interpolating the age of attainment, and then calculating a prediction value from it. The potential importance of the age of prediction was outlined by Smith (1991). She states that prediction ages are more accurate than attainment ages because the latter only describe individuals at that particular age. Prediction ages, on the other hand are calculated as the mean between one attainment age stage and the next stage, taking into account more variation in age. Smith herself provides interpolated data tables from Moorrees et al. (1963b) for both attainment and prediction ages. It should be noted that some of her interpolations are incorrect, and many of them differ from the interpolations calculated for this research. The differing results are due to individual interpretation of the difficult-to-read original box and whisker plots.

Saunders et al. (1993a) found that the combined standards of the Moorrees et al. (1963a, b) permanent and deciduous teeth predicted age most accurately. The Anderson et al. (1976) standards provided biased results because the reference sample does not begin until 3 years of age, thereby overaging the youngest individuals in the sample. They also found that the utilization of the Moorrees et al. standards for the maxillary incisors increased the age estimates as compared to the other teeth for each individual. This they attribute to the late stage of development for which the data begins (crown complete), and the fact that the information was drawn from a separate sample of children. Calculations of within-individual coefficients of variation of age estimates were undertaken, and the ranges were from 1 to 52. This is a broad range of variation, as recognized by the authors. They did, however, find that there was an inverse relationship between the number of teeth scored and the variation in age. This did not occur until there was a minimum of 6 teeth scored, and their sample usually had 5 or less. The authors note that Smith's (1991) coefficients of variation are much lower, reaching only 36. This they suggest is due to the fact that she always had six or more teeth available for scoring. The high coefficients of variation in the Belleville sample also came from individuals in which the maxillary incisors had been used in the age determination (chi square tests were run for the mandibular ages and mandibular plus maxillary ages against the documented ages of the cemetery samples), consistently providing higher age estimates due to their late addition to the study (crown complete), and their derivation from a separate population. This they note serves to remind other researchers that

Smith's (1991) low coefficients of variation for fossil Pan and human specimens are not necessarily reflective of the truth, as the sample sizes are small and may not present the full picture of population and sample variation. Similar results utilizing the coefficient of variation statistic have been recognized by Cope and Lacy (1992), and Plavcan (1989).

The final phase of analysis in this article compares the age of attainment results to the calculated age of prediction results (derived by the researchers) based on both the correct and incorrect sex designation for the known individuals. They found that the age of attainment values prove to be no less accurate than the age of prediction models for their sample and suggest that the extra step is superfluous. In addition they note that error is already introduced by the difficulty of interpolation from the Moorrees et al. (1963a, b) graphs, and that the error will be translated into the prediction ages. In their concluding paragraph, the authors state that prediction stages may prove to be more accurate when larger samples have been tested. Interestingly, the researchers found that there was no difference in accuracy of age determination no matter whether the correct sex, or the incorrect sex designation was used. However, their test sample was small (10 individuals), and consisted mostly of individuals under 5 years of age, a period when dental development is very similar between the sexes. Lastly, the researchers state that the standard deviations of age estimates decrease with increasing number of teeth used for any individual; therefore, researchers should use as many teeth as possible to derive age at death (Saunders et al. 1993a).

The important methodological points derived from Saunders et al. (1993a) for the purposes of the present research are that the Moorrees et al. (1963a, b) age estimation standards provide the closest approximation to chronological age, mainly because the standards are derived from children beginning right after birth, unlike the other methods tested. Additionally, there is questionable need to take the extra step to derive prediction ages from age of attainment stages. The results derived from age estimation using this method have a standard deviation of error of  $\pm 0.53$  years. This is approximately 6 months on the tested sample, which is derived from a similar ethnic background to the reference sample, but archaeological in context. Finally, the permanent maxillary incisors consistently overage individuals and should not be utilized. The samples studied

in the research undertaken by this writer consist only of mandibles, as maxillae cannot be paired with them. Excluding the maxillae does not skew the sample; but rather, makes it more representative of the true ages of the individuals.

As part of the same study on the Belleville skeletal sample, another article appeared by Saunders, Hoppa and Southern in 1993. This is the most comprehensive review of growth studies in skeletal samples from archaeological samples, and provides some important methodological innovations. The authors begin by reviewing all previous growth studies on skeletal samples, and provide specifics of sample sizes, aging method used, date of the sample and other information in an appendix (Saunders et al. 1993b:277). The problem with interpretations, they state, is the use of differing methodologies for constructing growth profiles. They assert that although some studies present standard deviations around the sample means, few calculate the confidence limits of individual sample means. They state that the confidence limits are dependent upon sample size and sample variance. Sample variance increases with age, and pooling data for both sexes will also increase the variance. This may cause incorrect assumptions to be made about the health of the samples when compared to growth curves from modern populations, as the confidence limits may overlap.

Saunders et al. (1993b) then propose to test the calculated “skeletal growth profiles” of the Belleville subadults using the Moorrees et al. (1963a, b) standards with modifications as suggested by the study of Saunders et al. (1993a). These are compared to growth curves for modern children (Maresh 1970), Protohistoric Arikara (Merchant and Ubelaker 1977), and a British Anglo-Saxon (Raunds) sample from the 10th century (Hoppa 1992). The data are presented graphically with means and 95% confidence intervals. It is apparent that the Arikara and Raunds samples exhibit growth deficits. The Arikara growth deficit begins around two years of age, and by 8 years of age, the confidence limits do not even overlap. The authors argue elsewhere (see review of Saunders and Hoppa 1993 below), that this represents a real biological difference in the living populations and is likely associated with malnutrition and infection. The Belleville sample closely follows the modern sample in height for age except for the first two years of age, where a slight growth deficit is noticed. The authors admit to a difficulty in

explaining this, and suggest that the individuals were probably not overtly stressed, but that the growth deficit may have been due to poor maternal health during pregnancy. The burials likely comprised a higher percentage of town as opposed to rural individuals. It is interesting to note that Vanderlinden (1995) found that breastfeeding was the norm for Belleville women, although it appeared that infants may have begun to receive supplemental foods as early as 5 to 7 months (Saunders et al. 1995). This was independently tested, and found to be corroborated by nitrogen isotope studies (Katzenberg et al. 1996, Herring et al. 1998). Additionally, the census data from 1851 to 1881 for Belleville shows that the most common occupation for women was as servants (Vanderlinden 1995:Appendix F). This may suggest that most women were not socio-economically advantaged, and that maternal health and nutrition did play a role in the growth deficit of newborn to 2 year old children. Biochemical analyses (isotopic and elemental) on bone have also been done on prehistoric samples, and the additional information which they have provided on stress at weaning age, and stress at the advent of agriculture will be discussed in Chapter 6, as some of the analyses have been done on the samples analyzed here, or closely related ones.

Saunders et al. (1993b) conclude their study by stating that because the Belleville skeletal growth profile is similar to that of modern children, this supports the theory that biological mortality bias does not always exist in a quantifiable way, and therefore selective mortality is of no issue. They state that the “stunting” seen in the growth profiles of the Arikara and Raunds samples are due to malnutrition and infection. They conclude that other researchers can use their growth profiles for comparison with samples from similar ethnic and temporal backgrounds.

Largely in response to Wood et al. (1992), Saunders and Hoppa published an extensive review on growth deficit and mortality bias in subadult skeletal samples in 1993. The main objective of the article is to demonstrate that the error introduced by methodology in interpreting health by growth deficit from skeletal samples is likely to surpass the error introduced into any study by biological mortality bias. They begin by questioning the assumption that “maturational or stress indicator data collected from the skeletons of deceased children accurately or even approximately represent the original

biological parameters of the living population” (Saunders and Hoppa 1993:127). Specifically, they are trying to determine if there is any evidence for *selective mortality* (Wood et al 1992), or *biological mortality bias* (Saunders and Hoppa 1993) producing mortality samples with significantly different subadult stature distributions than their corresponding living populations. The first section reviews some of the osteological analyses of growth (all of which are reviewed above). Cultural mortality bias is defined as differences in mortuary practices which will have an effect on who is interred in the cemetery, and environment mortality bias is defined as the result of differential effects of skeletal preservation. The authors state that these two types of bias could prove to be potentially more important to osteologists than biological mortality bias, yet most researchers have ignored them. Various opinions on biological mortality bias are reviewed. The general conclusion at which the authors arrive is that most researchers recognize and note that biological mortality bias exists. Further than that, because it cannot be defined, or even approached, assumptions are made that its effect is minimal. The opinions of Sundick (1978) and Cook (1981) as reviewed above are examples.

Saunders and Hoppa (1993) then review child survival research on living populations from developing nations. The first few years of life, the period with the greatest growth velocity and nutritional demands, is the period when adverse factors can have a significant and lasting effect on growth (Haas 1990, Martorell 1989). If a child undergoes “stunting” during this time, which includes the weaning period, and becomes “stunted” then he or she will be consistently short for age throughout the rest of the growth period into adulthood. The process of stunting can be reversed by catch-up growth, but once an individual becomes stunted, this does not change.

The well known synergistic effects of infection and malnutrition (Scrimshaw et al. 1959) are next discussed. They state that stunting and impaired linear growth is “clearly associated” with chronic infection. Diarrhoeal disease, particularly associated with infants who were not breastfed (and therefore did not receive the passive immunity to some infections from their mothers) is highly correlated with stunting. A lack of breastfeeding and diarrhoeal disease are also associated with higher mortality. One prospective study (Guerrant et al. 1983) is cited in which children 1 to 2 years old who

had diarrhoea in a three month interval, grew 41% less than children who had not experienced diarrhoea during that interval. Many other factors were well-controlled in this study. The role of sociocultural factors is also addressed. Saunders and Hoppa then review both the direct and indirect evidence for stunting and increased mortality risk from studies on living children in developing countries. The conclusion of the majority of these studies is that there is a strong correlation between growth deficit and mortality. Growth deficit or stunting is due to malnutrition which can have its roots in many causes both pre-and post-natal, and infections are equally large contributing factors. A fact that is clear from these studies is that growth stunting is defined by anthropometric measurements (including height for age), and is in turn used to classify nutritional status. It is interesting that skeletal biologists are doing a similar thing with skeletons. This association of mortality with failure to thrive (or stunting) is greatest in the earliest years of life, to approximately 3 years of age. The authors remind the reader, that although this correlation exists (stunting - infection - mortality), one should not assume that stunting places an individual at a greater risk of dying, just that the same factors which cause stunting and stunted growth, may also cause death. There is, however, a biological mortality bias in modern populations as revealed by the reviewed studies, and the authors turn to the implications for past populations. They construct a model using both real and hypothetical samples with differing mortality rates and nutritional statuses. Both survivor and non-survivor distributions of height for age are produced. The mortality bias is calculated by the difference in means of height between survivors and non-survivors. The result is that survivors are, on average, always larger. This difference is significant in all but one of the six samples. This suggests that the magnitude of the biological mortality bias is large. They take the test one step further by taking the percentage of total height for age represented by the femur for each age cohort and converting it into an actual measure (or stature). This quantified mortality bias is then compared to the data of Maresh (1970). The magnitude of the difference in attained height for age between survivors and non-survivors is minuscule in most cases, ranging from 0.175 mm to 2.860 mm. The authors assert that this test illustrates that the problem of biological mortality bias in skeletal samples is not great, and that methodological problems are greater. Their next challenge is the observed growth deficit in the 2-4 year age cohort, usually attributed

to weaning age deaths which many researchers have suggested (Katzenberg et al. 1996, Wall 1991). The authors set out to prove that the simple use of different age standards could alter the distributions in death of the age cohorts. Following on their earlier work (Saunders et al. 1993a), they found that the diaphyseal lengths for the subadult Belleville individuals fell below modern means when the individuals were aged by including the dental standards of Anderson et al. (1976), and the maxillary incisor standards of Moorrees et al. (1963b). When the standards of Moorrees et al. (1963a, b) for only mandibular teeth are used, the curve more closely approximates the modern growth curve, since the ages are adjusted down. The reader is reminded that the truncation of the Anderson et al. data and the truncation and different reference population for the Moorrees et al. maxillary incisors tend to overage individuals. The results of Saunders et al. (1993b) are also reiterated, reminding the reader that standard deviations for diaphyseal length in any given age cohort can range from 9 mm to 36 mm, largely due to the cross-sectional nature of the skeletal samples. These methodological problems introduce a standard deviation of  $\pm 6$  months into any age determination. It is my opinion that a standard deviation of 6 months will move an individual's age up or down only one year, and this may not affect the overall conclusions about a sample's health. This depends of course upon what is being suggested, and the precision necessary to prove it, as well as the size of the sample being studied. Saunders and Hoppa then directly address the interpretation forwarded by Wood et al. (1992), and outlined above, that high mortality rates will result in more children of average and tall stature being included in a skeletal series, while children of "stunted" stature will appear mostly in low mortality profiles. They cite Hass (1990) who states that short stature in and of itself is not a contributor to death, but rather the factors that lead to stunting may also lead to early mortality for a child (e.g. malnutrition and infection). Saunders and Hoppa (1993:145) state:

“We would argue, then, that their model, as they present it (Figure 6 in Wood et al. 1992) is unrealistic as it assumes identical living distributions of stature in the high mortality and low mortality populations. Clearly, if mortality is significantly higher and the cause(s) of death remain the same then the increased morbidity associated with an increased mortality rate could serve to reduce the overall living population mean and effectively shift the living distribution slightly to the left under conditions of high mortality”.

Saunders and Hoppa (1993) then present the findings of Saunders et al. (1993b) again by comparing smoothed growth curves (a second order polynomial which has greater correlation coefficients than a simple linear equation) for Belleville, Raunds (Hoppa 1992) and modern children (Maresh 1970). The modern and Belleville curves match almost perfectly, while the Raunds curve is substantially below both of them, suggesting that biological mortality bias is minimal or absent in some samples, while in others, its presence reflects real differences in health.

The authors (Saunders and Hoppa 1993) conclude by stating that short stature in children does not indicate increased risk of morbidity, but is a by-product of it. Environmental, cultural and methodological bias in skeletal analysis will likely be greater than actual biological mortality bias. If it does exist, and is identified, researchers must take care to carefully control population variability and aging techniques before they make any conclusions about the health of past populations.

Many methodological problems and questions of cultural and environmental bias have been addressed recently with the excavation and analyses of historic cemeteries, for which census data in varying forms exist (see the papers in Grauer 1995, and Saunders and Herring 1995). While the results of analyses on historic cemetery samples cannot be directly compared to prehistoric Native samples, the analyses of these samples have included research on methodological error and have shown that these errors may be reduced. This suggests that utilizing the methods which have been shown to work best by being tested on historic cemetery samples with documented evidence of culture, should perform equally well on skeletal samples that do not have the benefit of this additional information. In essence, these samples are the best available for testing methodology, and do not have to be ethnically similar. It may however be stated that a

number of the samples studied (e.g. from poorhouses) can be said to have been living in similarly disadvantaged conditions to the post-contact Native samples.

In 1993 Goode et al. addressed the environmental bias of preservation in skeletal samples by proposing a statistical standardization method for filling in missing data in growth velocity curves of subadults due to fragmentary remains. Goode et al. propose using the measurements of all extant bones from an individual aged by dental standards, and comparing them to the standards of Maresh (1955) for the mean long bone length for that bone and age, sexes pooled. Each bone measurement is divided by the average (of sexes combined) provided for an individual of that age. The obtained value, or proportion is called  $\delta_i$ . When more than one bone is present for a skeleton, the values are averaged to produce a  $\delta_{i \text{ mean}}$ . A value less than zero (unity) indicates a bone shorter than the standard, while a value greater than zero (unity) indicates the opposite. A test sample comprised of juvenile bones from a British site indicates that there is no significant correlation between age and  $\delta_i$ , and that age accounts for only 0.7 % of the variance in  $\delta_i$  when linear regressions are performed on the data. The method allows age derived from different bone lengths to be plotted on the same graph, and to determine if the individuals were short for their age. The authors suggest that the method is very useful for comparing samples across geographic areas or in temporal sequence within a single geographic area, as the use of a standard (in this case the data of Maresh 1955), makes all data comparable.

Hoppa and Saunders (1994) had reservations regarding the method of Goode et al. (1993), and tested it on their Belleville data. First they investigated if the standard error of the  $\delta_{i \text{ mean}}$  would increase for individual age cohorts with the increase in the number of bones from a mixed assemblage as opposed to single bones. This is an important consideration because ratios which control for size, as does  $\delta_{i \text{ mean}}$ , could possibly change the distribution of the data (Albrecht et al. 1993). They found that there was no change in the standard errors with the new method. Additionally, they found that there was no added information on bone size distribution to be gained from using the statistic (it did not change the shape of the curve), except that it increased the N. Finally the authors suggest that the use of the  $\delta_{i \text{ mean}}$  may artificially push some measurements above

zero (unity) when limb proportions are different. They cite the example of humeral lengths being significantly greater than femoral. Mixing the two results together not only obscures information about limb proportionality, but may suggest erroneous long bone lengths when limb proportionality is not known. They conclude by commending Goode et al. (1993) for suggesting a method to standardize growth studies, but suggest caution in its use. The best age determination method for subadults remains the Moorrees et al. (1963a, b) dental method.

Liversidge (1994) reports on her tests of dental aging techniques using the Spitalfields skeletal sample of known age and sex individuals. Although this paper does not discuss or utilize North American Native samples, it raises some important methodological challenges. On a sample of children from birth to 5.4 years of age, she tests the developmental stages of the Schour and Massler (1941) method, the Gustafson and Koch (1974 - this is incorrectly cited as 1985 in Liversidge) method, The Moorrees et al. (1963a) deciduous teeth calcification method, the Moorrees et al. (1963b) permanent teeth method, and the modified Moorrees et al. prediction age method (Smith 1991). Tests of accuracy (mean difference between dental and known age) indicate that she had the least success with the dental calcification standards, and the most with the Gustafson and Koch diagrams and Schour and Massler chart. The differences for the Moorrees et al. (1963a, b) method as compared to the known ages were statistically significant. Interobserver error tests reveal the inverse, with the most repeated precision with the calcification standards, and the least precision with the Gustafson and Koch diagrams, although none of the mean differences were statistically significant. Sex specific standards were used.

The results of her analysis may appear to cast the validity of the Moorrees et al. (1963a, b) standards into doubt (even though the test is on a British historical population), but upon closer observation, her results are reflecting the limits of the use of this method, as opposed to its accuracy. To begin with, Liversidge (1994) does not state how many teeth were utilized to interpret the age of each individual; the fewer the teeth, the more the chance for being incorrect with an age determination. She does state that many of the specimens were fragmentary and incomplete. Second, her age subdivisions are in three

month increments, with the bulk of her sample falling in the birth to 3 month category. There are only two calcification stages for the deciduous canines and first molars, and one for the second deciduous molars that provide information on age for individuals this young. Only one permanent tooth provides a single age for this cohort. If any of her sample did not display these stages, then they could not be aged by the Moorrees et al. deciduous or permanent standards. Up to 6 months, two more stages for each of the teeth mentioned above are added. Infants less than 6 months constitute 27 % of her sample. 46% of her sample is, in fact less than 1 year of age. Only 70 to 75% percent of the sample was actually aged by the methods of Moorrees et al. As Saunders and various co-workers have stated repeatedly, a method is only useful if the methodology is sound. It would appear that a small sample (N = 42 or 47), an overabundance of neonates within the sample, and an expectation of precision (to 3 months) combined to make the standards of Moorrees et al. appear less accurate than other tests have shown. Saunders et al. (1993) state that the method is only accurate to  $\pm 6$  months; therefore, the results of Liversidge's analysis are not unexpected. In addition, the Schour and Massler charts only present means for birth, 6 months and 9 months (prior to one year). It is not stated how Liversidge redistributed her age determinations to fit into 3 month intervals. A more critical assessment of the problem could be addressed if the number of teeth contributing to an age were known. All of the methods Liversidge uses underage the individuals to some extent. This may represent a consistent misinterpretation of a development stage, or may be saying something about the actual biological propensity for advanced dental development in this population. The latter is suspect, as so many studies have shown the consistency of dental development within samples of European descent.

While not a growth study, per se, Hoppa and Gruspier (1996) tested a method for increasing the number of "ageable" diaphyses within a sample, theoretically similar to the work of Goode et al. (1993). Measurements of both diaphyseal end breadths of the subadult humeri, radii, femora and tibiae of Fairty and Kleinburg were investigated. All of the end breadth measurements exhibit a strong correlation with the lengths of the bones in a linear or curvilinear fashion. Regression models were applied to the data to derive prediction equations for the diaphyseal lengths from the combined data of the two samples. These prediction equations were applied to two different populations to test for

accuracy, and were found to be variable in their prediction ability, underscoring the need to derive prediction equations which are population specific. The authors then combined the diaphyseal lengths with the predicted diaphyseal lengths to produce a new subadult mortality profile for the Fairty ossuary. The results were an increase in the ageable sample size by over 100%, particularly in the under 5 age cohorts, which appreciably modifies the shape of the mortality curve. The dental age of these individuals could not be compared, as the sample was disarticulated, and age was determined by transforming the observed and predicted diaphyseal lengths according to the standards of Merchant and Ubelaker (1977).

With the exception of one paper (Liversidge 1994), all of the reviewed research suggests that the best method for aging juvenile archaeological material, regardless of its cultural affiliation, is by dental calcification standards. Independent tests of accuracy have suggested that the method of Moorrees et al. (1963a, b) is the best, in that it has the least amount of inherent error, and follows children from the youngest age (2 months). All researchers agree that dental age most closely reflects true chronological age. Diaphyseal ages, transformed by some set of age standards, have evolved from being used as indicators of growth in the past to indicators of child health. In particular, researchers appear to agree that although a growth deficit (or “stunting”) does not necessarily indicate that a child was more likely to die, it does indicate that the child was malnourished in some way. A number of studies take this further by analyzing the rates of indicators of non-specific stress on the skeletal remains in their sample. The evidence suggests that chronic or acute infectious disease is also strongly correlated with malnutrition, stunting, and risk of death in childhood. In particular, this deficit in growth has been demonstrated in the toddler age group by both deficit in length of diaphyses and in the width of long bone diaphyses. A suggestion that this is caused by the change in diet at weaning has been explored by isotope studies (Herring et. al. 1998), but to date, it has only been confirmed that weaning did take place around the same age where the growth deficit begins to be seen in these samples, and only in those samples with documented historical evidence of weaning practices.

Whether the observed growth deficit in toddlers in these samples is actually due to the combined effects of malnutrition and infectious disease or whether it is reflecting a growth pattern which was normal for these populations is a question which must be addressed on a per-sample basis. The main problem with getting to this point are the methodological considerations. It must be hypothesized that the sample being studied, in some way reflects the living population, in order to infer anything about it. The questions of bias within samples must then be addressed. Cultural and environmental bias can often be assessed, but methodological bias is more difficult to assess and correct for. The most recent papers reviewed in this chapter forward the opinion that this cannot easily be done, if at all.

This study combines the methodological advances of previous studies reviewed here in an attempt to demonstrate a growth deficit in ossuary samples for the first time. It also attempts to assess the magnitude of error introduced by methodology and compare it to the observed growth deficit, in an effort to discover if any difference between dental and diaphyseal age in these samples is a true reflection of “stunting” of the subadults in the sample.

## **CHAPTER 3**

### ***The Samples***

The skeletal samples chosen for this analysis date from the Late Woodland Period of Southern Ontario prehistory. The Late Woodland Period is considered to begin after approximately 900 AD (Smith 1990). The Late Woodland Period encompasses the Western Basin Tradition and the Ontario Iroquoian Tradition. The Ontario Iroquoian Tradition is further subdivided into the Early, Middle and Late Iroquoian Stages (along with a number of substages), and it ended approximately 1650 AD. The geographical area from which the skeletal samples derive is South-central Ontario. The use of the Ontario Iroquoian Tradition terminology proposed by Wright (1966) is generally still accepted as a framework for interpretation of Southern Ontario Iroquoian pre- and proto-history, although some of the components of the framework, and their underlying theories have been recently questioned, in the light of additional data (Smith 1990:287). The most comprehensive review to date, of the archaeological history of Southern Ontario can be found in the papers in Ellis and Ferris (1990).

The health of the Native Ontario peoples before and after contact with Europeans has always been a subject of interest in Southern Ontario osteological studies. This particular study analyzes possible growth deficits in juveniles, which are interpreted as being indicative of malnutrition and infectious disease load, by some. In order to permit the possibility of comparing growth deficits through time in Southern Ontario, samples from both before and after contact with Europeans were chosen. In order to obtain a large sample of juveniles, only burials with a large MNI were considered. Samples from The University of Toronto, The Royal Ontario Museum and the Canadian Museum of Civilization were investigated. The samples analyzed for this research derive from the early-agricultural Fairty Site, The circa-contact Huron site of Kleinburg, and the two Neutral, post-contact sites of Milton #1 and Carton. All data was collected for the Milne and Milton #2 samples, but the number of individuals was too small to include. In addition, they had no contemporaries amongst the other samples, and therefore could not be combined with them.

In the original proposal of research for this study, a number of other sites were included. For various reasons, many of these collections were found to be unsuitable, or simply unobtainable. The omission of the Milton #2 and Milne ossuaries is discussed above. The remains of the Orchid ossuary were originally going to be included because of their presumably early date, which would have put them immediately following Fairty (1300 to 1500 AD) (Molto 1983:98). Inquiries were made to Dr. J. Cybulski at the Canadian Museum of Civilization as to the possibility of including this site. Dr. Cybulski informed the writer that the ossuary had been de-accessioned, and was packed and awaiting reburial. In the intervening period, new information regarding the date and nature of the remains has come to light. The site is dated AD 1380  $\pm$  90 (Beta Analytic Inc. Lab # 13323; 410  $\pm$  90 BP)(Birx 1991:11). It is also known that it was not completely excavated (Birx 1991). The inclusion of this site would have filled the gap in the data concerning the prehistoric Neutral. Since the time of preliminary inquiry into the inclusion of the remains in this study, the remains have been reburied.

The extremely important Ossossané ossuary also had to be excluded. The long bones of the juveniles are too damaged and eroded to gain sufficient information from. Many of the juvenile mandibles are likewise eroded, and the teeth cracked, which would have interfered with the quantification from the teeth. Apparently, the remains from this ossuary were not always preserved so. Immediately post-excavation (in ca. 1957), they were stored in the Department of Anthropology at the University of Toronto and the Royal Ontario Museum. Most of the collection was then taken to a university in the United States for analysis. Some "display pieces" remained at the ROM. There was a flood shortly after and these bones suffered water damage. (H. Deveraux pers. com.). The material remaining at the St. George campus and the ROM was then moved to Erindale campus where the bones sent to the United States were shortly thereafter, returned (J. Melbye pers. com.). Scattered bones and artifacts are still being recovered in the Department of Anthropology's St. George facilities. The artifacts do not seem to have suffered the same fate. The inclusion of this site would have provided a glimpse of the Huron during the French period, and any demographic or pathological information acquired from this ossuary would have been interesting, as the Huron were already succumbing to the ravages of European introduced disease when the burial occurred. At

the time of writing, the remains from this ossuary have been removed back to the Royal Ontario Museum, where they are being re-packaged for imminent reburial.

The Glen Williams ossuary is a large prehistoric Neutral ossuary, which would have been superior to Carton and Milton for use in this analysis. All of the teeth have been forcibly extracted from the mandibles, with no clue as to which teeth came from which mandible, and no copy of the apparently important research which resulted from this destruction. For obvious reasons, this site could not be utilized.

Uxbridge was omitted early in the analysis. At the time it was curated in boxes by its original excavation units at the University of Guelph. Initial attempts at searching each box, removing the pertinent portions, labeling them by provenience number and attempting to mend them were made. Access to the material was limited, and it had to be excluded from the study. The Uxbridge ossuary has recently been moved to the University of Toronto at Mississauga. It is large, well excavated, and from a period not represented by other samples in this analysis (Early Huron: Black Creek-Lalonde Period, ca 1400 to 1500 AD). It is the intention of this writer to analyze this sample in the near future.

A brief chronology of the periods of Southern Ontario prehistory from which these samples derive is presented in tabular form below (Table 2).

<b>DATES</b>	<b>CULTURAL STAGE</b>	<b>CULTURAL SUBSTAGE OR BRANCH</b>	<b>SITE</b>
900 to ca. 1300 AD	Early Ontario Iroquoian	Pickering Branch	FAIRTY
1300 to 1400 AD	Middle Ontario Iroquoian	Uren Substage (1280 to 1330 AD)	
		Middleport Substage (1330 to 1400 AD)	Fairty (traditional)
1400 to 1650 AD	Late Ontario Iroquoian	Huron-Petun Branch: Black-Creek Lalonde Period (1400 to 1500 AD)	
		Realignment Period (1500 to 1600 AD)	KLEINBURG
		French Period (1600 to 1649 AD)	Milne
		Neutral-Erie Branch: Prehistoric (1400 to 1500 AD)	
		Pre-Fur Trade (1500 to 1580 AD)	
		Fur Trade Glass Bead Period 1 (1580 to 1600 AD)	CARTON
		Fur Trade Glass Bead Period 2 (1600 to 1630 AD)	? MILTON ↓
		Fur Trade Glass Bead Period 3 (1630 to 1650 AD)	

*Table 2: Summary of the chronology of the Late Woodland Period, Ontario Iroquoian Tradition, with sites utilized in this study.*

### **A Brief History of the Periods**

The Late Woodland Period in South-Central Ontario, also called the Ontario Iroquoian Tradition, encompasses the developmental stages of the societies of Iroquoian

speaking peoples in that part of Ontario. Archaeological investigation is constantly refining the definitions and dates of this period. At present, most researchers agree that it is characterized by the practice of cultivation (particularly imported crops), and the habitation of semi-sedentary villages. Additionally, it is thought that these traits developed gradually, and were an in situ phenomenon (Smith 1990). The most contentious issue at present, is dating the beginning of this period. Fox (1990) summarizes the various definitions of the Late Woodland Period, based upon either material culture, mortuary or settlement definitions. Not surprisingly, different dates for the beginning of the Late Woodland Period (or end of the Middle Woodland Period) are derived, depending upon the medium being used for definition. Most researchers appear to accept that the Princess Point Complex preceded the Late Woodland Period, and shows a cultural transition with it. This culture is dated to approximately AD 500 to 900 (Fox 1990, Smith 1990). The real problem with dating the beginning of the Late Woodland Period, until recently, was the lack of Princess Point Complex sites, and particularly those with carbon 14 dates. Smith (1997) undertook to remedy this problem by presenting a series of new and recalibrated dates from sites in Southern Ontario. Recent radiocarbon dates on maize from a South-Central Ontario site place the introduction of this cultigen as early as AD 500. The recalibrated carbon dates show that there is an overlap of Middle and Late Woodland between AD 500 and AD 800. Smith's revised chronological framework has the Princess Point Complex covering the period between AD 500 and AD 1050, and the Early Ontario Iroquoian Tradition beginning approximately AD 900. There is much overlap with dates between sites.

The controversy surrounding cultural definitions and dates continues with the Early Iroquoian Stage. This stage of the Iroquoian Tradition is dated approximately AD 900 to 1300 (Williamson 1990). Many of the problems with defining this period in prehistory stem from Wright's (1966) original definitions of the Glen Meyer and Pickering Branches of Early Iroquoian societies defined by ceramic typology. In his theory, the appearance of the South Western Glen Meyer pottery types in Late Pickering and Middle Iroquoian contexts suggests that the Pickering peoples moved into South Western Ontario and "conquered" the indigenous Glen Meyer peoples, while continuing to develop their own culture in South Central and South Eastern Ontario. Williamson

(1990) reviews the more recent attempts at defining new theoretical frameworks for this period by delimiting such constructs as subsistence, social, political, settlement, and ideological, and the systems in which they worked. The date of inception of this period is unclear, but most researchers agree that it terminated by AD 1250 to 1300 (Dodd et al. 1990).

Leaving aside the problems with continuing to utilize the “Branch” definitions of Wright (1966) (which most researchers appear to acknowledge, although they continue to use them), a more in depth summary of the Pickering Branch is necessary here. The recently obtained radiocarbon dates for the Fairty ossuary may potentially date it within this time frame, and possibly even back into the Initial Late Woodland (or Princess Point) as opposed to its traditional Middleport date (see below). Analysis of skeletal remains has suggested that the Early Iroquoians gradually became more reliant on maize, while continuing to hunt and fish (Katzenberg 1984, Patterson 1984, Schwarz et al. 1985). Part of this theory has been constructed based upon the assumption that Fairty was of a later, Middleport date, this will be discussed further, below. Further evidence for this continuing reliance on hunting and fishing is noted by Kapches (1982), who documented only fishing camps and small village sites with little maize in her review. Williamson (1990) counters that this hypothetical continued reliance on hunting and fishing, with seasonal and sporadic horticulture, as has been demonstrated in the Middle Woodland Period, cannot be tested, as there has not been any concentrated excavation in a single region. Early Iroquoian houses are small compared to those of later stages, but gradually increase in size throughout the stage. The villages are generally small, but tend to exhibit much evidence of rebuilding of structures, and general disorganization. The house patterns within the villages have been cited as evidence of low populations and weakly organized or absent governments (Williamson 1990). Burial practices of both branches of the Early Ontario Iroquoian Stage defy an overall definition. There are primary burials within houses (Bennett site), primary and secondary burials (both single and multiple bundle burials) together on a site (Miller), and “true ossuaries” (periodic mass reburial of largely disarticulated remains) (Serpent Pits). There is not enough evidence to define a “mortuary program” for this period (Spence 1994).

The Fairty ossuary has been traditionally assigned to the Middle Ontario Iroquoian Stage for reasons given below. This stage is dated approximately AD 1300 to 1400, and divided into two Substages (Uren and Middleport) (Wright 1966). There is some controversy over the continued acceptance of these two Substages, and their dates (Dodd et al. 1990). A good number more Middle Iroquoian sites have been excavated or surveyed than Early Iroquoian sites. Villages of the period are approximately twice the size of the Early Iroquoian village, as are the houses within the village. Settlement size has been suggested to have been a result of an increased reliance on maize. Socio-political factors have been hypothesized by some, but the evidence for a well developed government is lacking at most sites (Dodd et al. 1990). Burial practices during this period vary as they did in the preceding. Uren burials are few, with both primary and bundle burials being reported. The Tabor Hill ossuaries have traditionally been dated to the Uren Substage, and contain a mass of disarticulated individuals, bundle burials and cremations. Radiocarbon dating must be done for the remaining bones from this site, as until recently, it was the only example of a true ossuary from this period. The Moatfield ossuary has recently been excavated in Downsview, Toronto, and containing 90 individuals, and well-dated, it is the best "type" ossuary for the Uren period. The Fairty ossuary was the only true ossuary known from the Middleport Substage. Small secondary interments have been found at Middleport, Nodwell and Crawford Lake (which also has primary interments in houses) (Dodd et al. 1990). Burial practices from this period seem little different to the preceding one.

In South Central Ontario, the Late Iroquoian Stage saw the development of at least two distinct Iroquoian groups; the Huron-Petun and the Neutral-Erie. Both cultures are well-known from archaeological and ethnohistorical sources. They are considered to have been tribal confederations which lived in organized villages and relied on agriculture for subsistence (the Huron-Petun perhaps more than the Neutral-Erie in this regard (Fitzgerald 1990, Lennox and Fitzgerald 1990, Ramsden 1990). Burial practices vary for both groups, with more large true ossuaries known from the Huron. In-house primary interments, exterior primary interments and small multiple secondary interments have also been found. Ethnohistoric sources mention the practice of exposing a fresh body on a scaffold for later burial in an ossuary (Tooker 1964).

The Late Iroquoian Stage ended with the termination of the Huron-Petun and Neutral-Erie as confederations, in approximately AD 1650. In a relatively short-lived (700 years) period the Iroquois had evolved from small hunting and gathering bands to tribally affiliated villages subsisting largely on agriculture. The advance of the Iroquois Five Nations and the coming of the Europeans are said to be equally responsible for their demise (Heidenreich 1990).

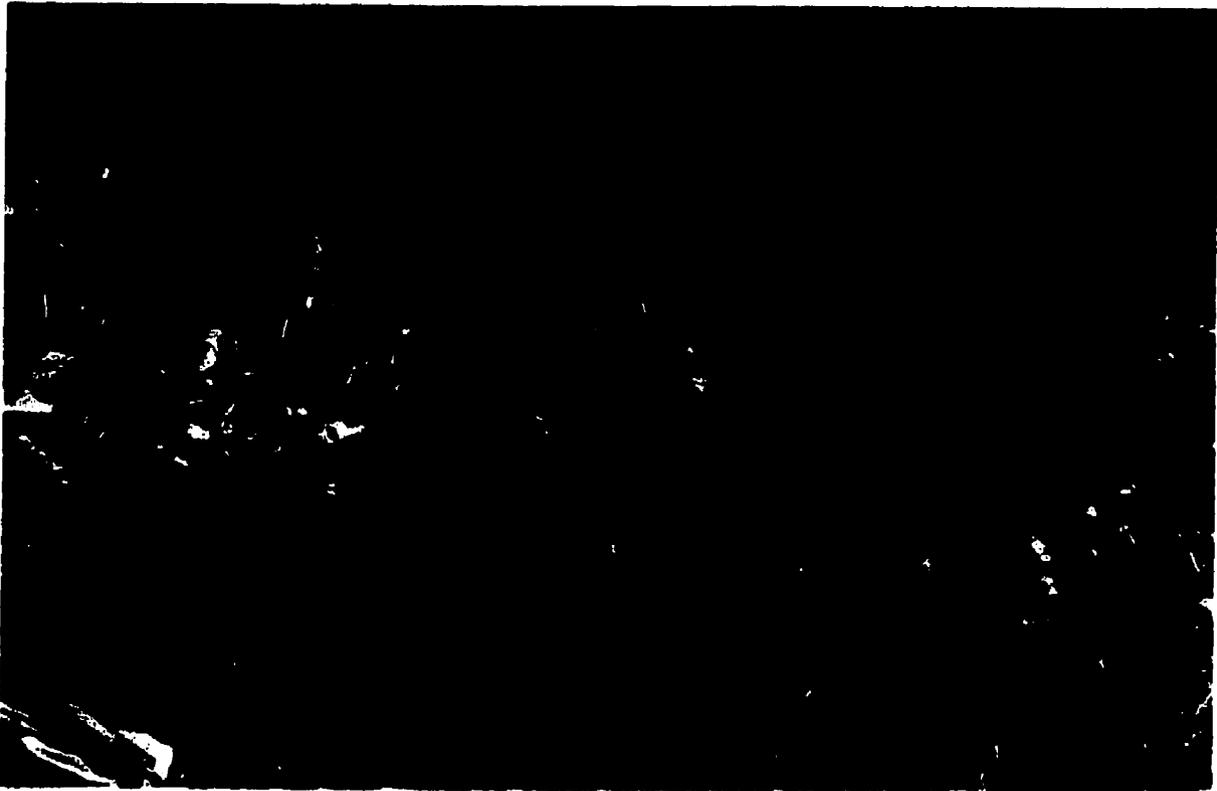
## **The Fairty Ossuary**

### ***Location and History***

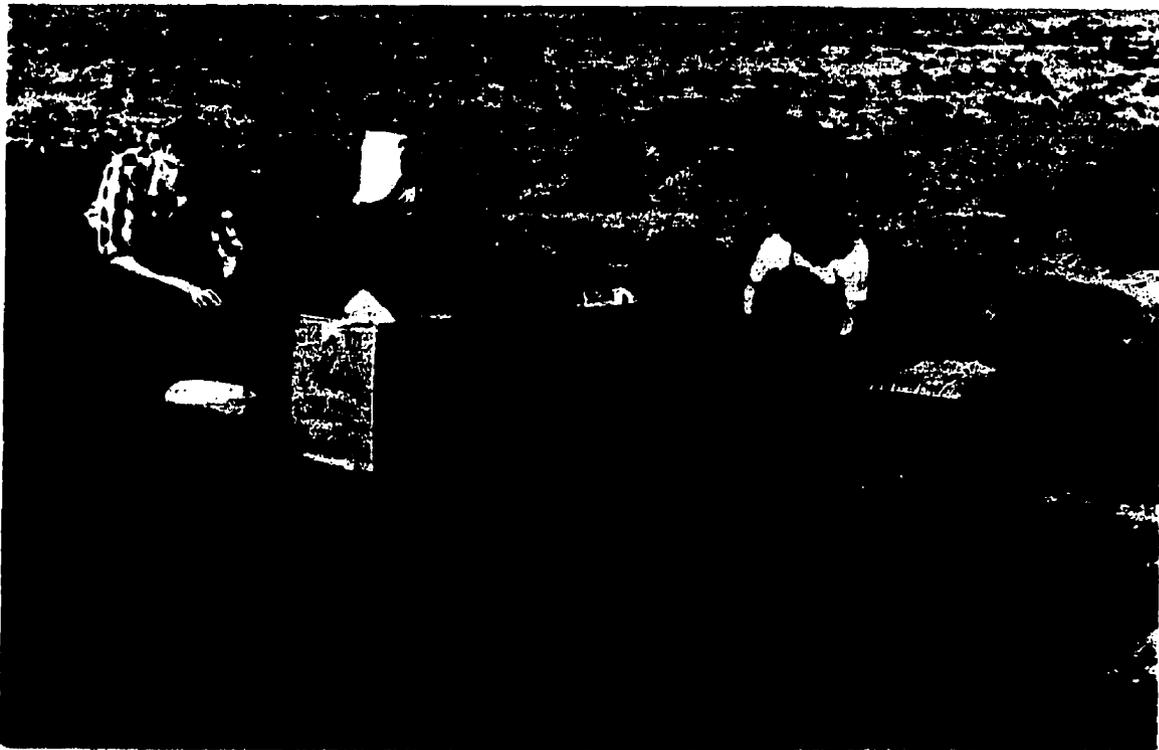
The Fairty ossuary (AlGt - 3) was located in Markham township, near Steeles avenue and Highway 48. Recent attempts to relocate the ossuary for purposes of archaeological assessment state that it was just over 500 m north of the Faraday site, and 1000 m north of the Robb site (Poulton 1998). The site was excavated under the guidance of Dr. Norman Emerson and Dr. J.V. Wright by the Ontario Archaeological Society in 1956, as part of the excavation of the Robb Site. A search for any documents pertaining to this excavation proved fruitless. A photocopy of the Robb Site field notes (originals presumably in possession of Mr. Donaldson) were found in a search of OAS documents in the possession of Dr. M. Latta. Excavations at the Robb Site were undertaken in 1954, 1955, 1956, 1958 (and 1962 by University of Toronto students) (Donaldson n.d.). There is no mention of the excavation of an ossuary in the vicinity in 1956. J. V. Wright states that the ossuary was 11 feet in diameter and 6 feet deep. It contained a scraper and a discoidal shell bead along with the bones (Wright 1966:61). The Ontario Archaeological Society does not have the field notes (C. Garrad pers. com.) and a search through the OAS files in the possession of Dr. M. Latta did not prove fruitful in this endeavor. The investigator who performed the first analysis of the skeletons did not recall seeing any field notes (Dr. J.E. Anderson pers. com.). That field notes were taken is suggested by extant photographs of the excavation in progress (W. Renison pers. com.). The existence of them is confirmed in the only brief publication on the excavation (Donaldson 1962). The original analysis was performed in the old anatomy building at the University of Toronto (Dr. C. Merbs pers. com.), following

preliminary sorting and labeling in the Sydney Smith house (now replaced by the Planetarium) (W. Renison pers. com.). The anatomy building has since been destroyed by a fire in which many records were lost (Dr. J.A. Duckworth pers. com.). It is unknown whether the excavation notes from the Fairty Site were lost in this fire, or if they are still in existence. They are not in the University of Toronto's, Department of Anthropology's archives. One photograph exists in the Department of Anthropology archives, and an extensive collection of photographs remains in the possession of the individual who undertook most of the photography for the Ontario Archaeological Society excavations. (Mr. W. Renison) (H. Deveraux pers. com.). A reference is made, in the original publication of the results of the analysis of the Fairty bones to "the notebooks of data, the files of analyzed statistics," (Anderson 1964:59). It is presumed that this refers to the notes and data taken during the analysis of the skeletal remains themselves, and it is unknown where these presently reside. Dr Anderson stated that he did not have them (Dr. J.E. Anderson pers. com.), and they have not been located since his death. Dr. Anderson treated the skeletal remains from the site as a true ossuary, that is to say, that no individuals were discerned in his analysis (Anderson 1964). The ossuary material remains boxed and stored by skeletal element in the University of Toronto, Department of Anthropology storage facility.

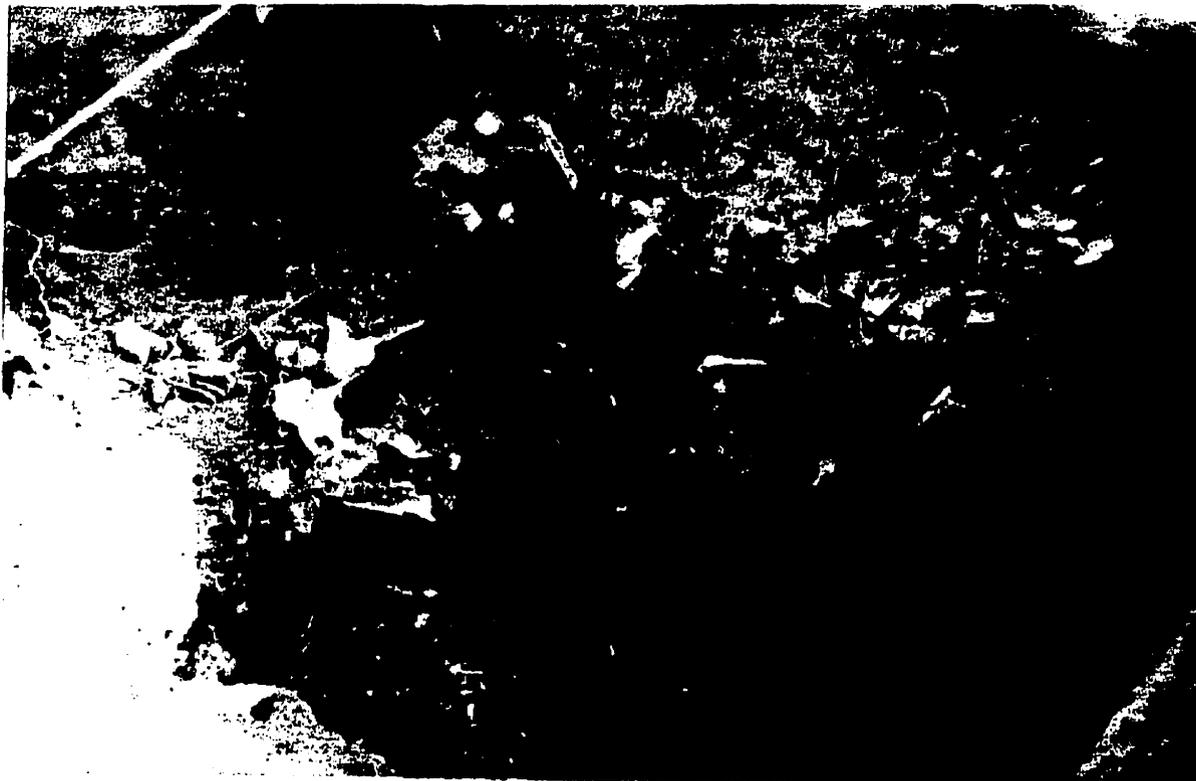
A visit to Mr. Renison proved very useful. Mr. Renison has approximately 100 slides of the excavation taken over the course of the three weekends of excavation. He kindly allowed this writer to copy a selection. The photos suggest that that the ossuary had not been looted (however, see below). The ossuary was discovered by Dr. Emerson while walking a plowed field approximately one-half mile from the Robb Site. The first photographs clearly show a plowed field with bones scattered on the surface (see photograph #1). The excavation was undertaken by gridding the area, and excavating the ossuary in quarters, leaving two criss-crossing baulks until the end of the excavation (see photograph #2).



*Photograph 1: Fairy Ossuary. Ground surface showing breach into grave and scattered bones. Photo taken by Mr. W. Renison, September 9 1956.*



*Photograph 2: Fairy Ossuary. Early stage of excavation showing circular pit and gridlines. Note edge of pit in section (right), and lack of bones in this upper level. Photo taken by Mr. W. Renison, October 7 1956.*

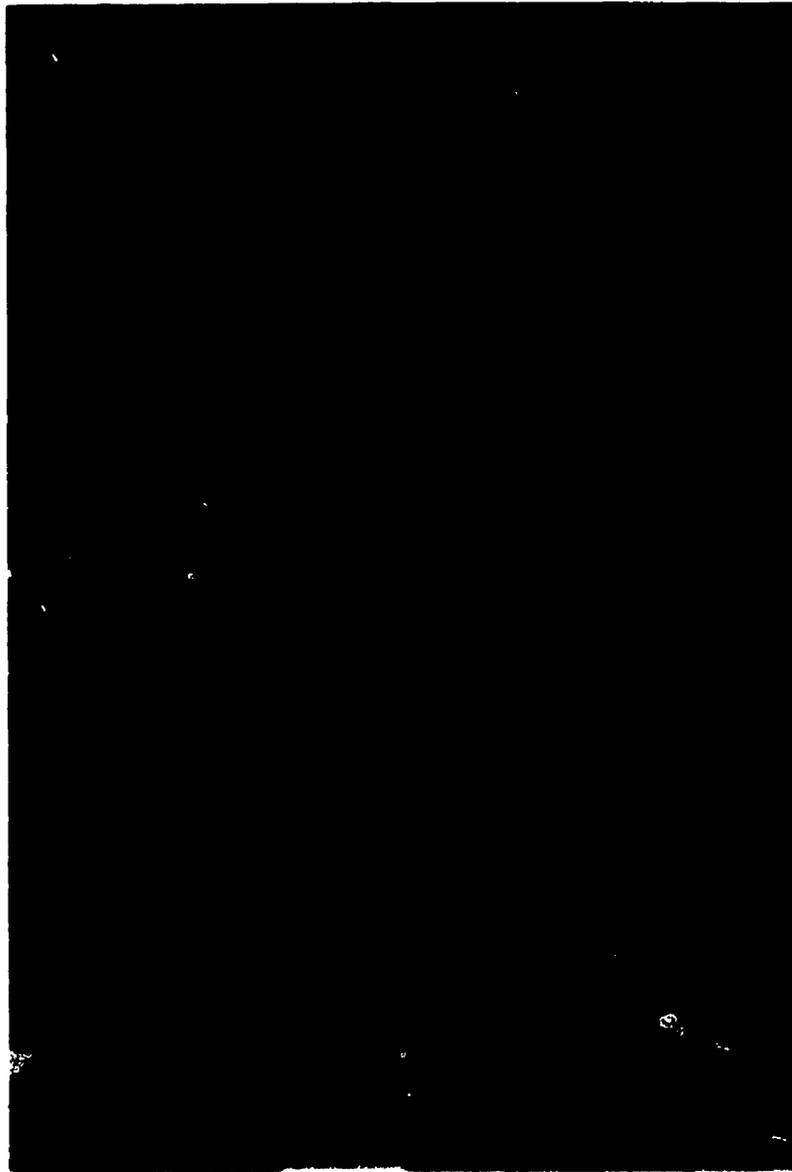


*Photograph 3: Fairry Ossuary. Section showing progression of excavation. Note ossuary edge in section and disarticulation of remains. Photo taken by Mr. W. Renison, October 14 1956.*

The bulk of the skeletal material was in the bottom of the pit, and was disarticulated (see photographs # 3, 5, 6). The pit was excavated to subsoil. One of the photos clearly shows that there is a bundle burial present in section (See photograph # 4). Such burials were not kept separate from the mass of disarticulated bone. Mr. Renison is of the opinion that field notes were taken, and are likely in the possession of one of the individuals who participated in the excavation. The Ontario Archaeological Society apparently stores such records with whomever has the space. That they are not in the hands of the excavator of the Robb site (Donaldson), was discovered during research for a recent archaeological assessment of the general area (Poulton 1998).



*Photograph 4: Fairry Ossuary. Detail of a bundle burial in section. Note articulated vertebrae in section, and excavated on the baulk.*



*Photograph 5: Fairty Ossuary. Remains near the bottom of the ossuary pit. Note disarticulation of remains. Photo taken by Mr. W. Renison. November 4 1956.*



*Photograph 6: Fairry Ossuary. Sections remaining in baulks. Note that this photo is on the opposite side of the baulk from photo # 4. Photo taken by Mr. W. Renison, November 4 1956.*

It would appear from the photos, then, that the Fairry ossuary was approximately 11 and a half feet in diameter, and five and a half feet deep (approximately 4 m in diameter, and 175 cm deep). The disarticulated remains were near the bottom of the pit, with at least one bundle burial higher up in the fill. It appears that approximately 50 to 75 cm of the soil filling the upper layer of the pit was relatively sterile, with few and interspersed bones in it. Mr. Renison also related that the OAS volunteers were

responsible for mending and labeling the bones under the direction of Dr. Anderson. Donaldson (1962) states that the burials were mostly in the form of bundles, or disarticulated. He also states that there was evidence of looting in the upper layers, suggesting this as a reason for the paucity of artifacts.

The bones of this ossuary have been utilized for teaching purposes over the past thirty years. Bones from this site were found in the teaching collection, in the Normal School Collection (which no longer exists as a collection), in boxes labeled “Dr. Daily’s Collection”, and at the Royal Ontario Museum. (Dr. Dailey was one of the OAS volunteers who excavated the site). All of the bones were put back into their appropriate boxes with the exception of a few on display in the teaching lab, and the couple of adult bones at the Royal Ontario Museum (ROM). These bones are in a box labeled “Anderson Teaching collection”, and were inadvertently sent to the ROM when the University of Toronto Anthropology department returned the ROM collections after curating them for a time in the 1970s. They should be returned to the University of Toronto’s collections. No loose teeth from this site could be located. A graduate of the Department of Anthropology (N. Sullivan) returned the Carton and Fairty juvenile mandibles commingled and freshly broken at the midlines. A fair amount of time was spent matching up hemi-mandibles in order to determine which site they had come from (only one side of the formerly complete mandibles had been labeled). It may be noted that Sullivan lists the “Fairty” mandibles which he radiographed and aged for his palaeodemographic reconstruction of the Fairty ossuary in Appendix A of his thesis (1988). This list clearly includes a number of individuals from the Carton site, by catalogue number. The juvenile sample of tibiae studied by Larocque (1991) were found separately, and returned to the correct boxes. Following completion of this analysis, a second box containing a large number of juvenile tibiae were recovered from elsewhere in the Department of Anthropology; these had not been available to Larocque. All of the adult humeri of the left side have been sectioned sagittally and horizontally at midshaft, with no metrical data on record for them. Most of the Fairty collection is now stored together, and the sample may be considered relatively complete (with the exception of the loose teeth) for future researchers.

### ***Fairty's Position in Southern Ontario Prehistory***

The Fairty Ossuary has been traditionally dated to the Middleport Substage of the Middle Ontario Iroquoian Stage (1350 to 1400 AD.). This is by its association with the Robb Site, and not by direct dating of the skeletal remains or artifacts themselves (Wright 1966:61). Recent site analyses and the addition of more radiocarbon dates from new sites have broadened the time range of the Middleport Substage to between 1330 and 1400 AD. With 512 individuals, Fairty is the largest known ossuary from this period.

The only other Middle Ontario Iroquoian ossuary which compares in size is the Tabor Hill ossuary (MNI = 213), which is purported to be slightly earlier, dating to the Uren Substage (1280-1330). This ossuary is in fact two adjacent burial pits (Churcher and Kenyon 1960). As is the case with Fairty, no *diagnostic* artifacts were recovered during the excavation of this site, and it is dated by association with the Thomson Site which is 2 km. away (Churcher and Kenyon 1960:253). The Tabor Hill ossuary pits are currently being analyzed by students at McMaster University under the guidance of Dr. S. Saunders, and there are no plans to radiocarbon date samples from it (S.Saunders pers. com.).

An integral part of this research was to provide a date for the Fairty Ossuary. Two samples were taken and sent to the Isotrace Radiocarbon Laboratory, University of Toronto, for radiocarbon dating utilizing the accelerator mass spectrometer. The results are presented in Table 3 below.

<b>SAMPLE NUMBER</b>	<b>RADIOCARBON DATE</b>	<b>CALIBRATED DATE (95.5 %)</b>
TO-3549	1190 ± 50 BP	CAL. AD 710 (880) 980
TO-3550	970 ± 50 BP	CAL. AD 990 (1030) 1210

*Table 3: Radiocarbon dates for the Fairty ossuary. The calibrated dates were generated using the Stuiver and Pearson (1993) calibration tables and were calculated using CALIB v.3.0.3c for Macintosh (kindly provided by Dr. D. Smith).*

The radiocarbon dates place the Fairty ossuary in the Pickering Branch of the Early Ontario Iroquois Stage, beginning approximately AD 900, utilizing traditional dates (Williamson 1990). According to Smith's (1997) revised chronology, Fairty may also be Princess Point, or Initial Late Woodland. In either case, radiocarbon dates place Fairty in a "transitional" Woodland stage. In the absence of any cultural information from the ossuary or a site associated with it, the scale of agriculture being practiced by the Fairty group cannot be addressed (however, see Chapter 6 for comments on elemental analysis of the remains). Fairty would then be contemporary with Serpent Pits and Force Site, and earlier than the Miller and Bennett<sup>3</sup> Site (to name some of those Pickering/Glen Meyer and Princess Point sites with human skeletal remains only). The validity of radiocarbon dates from bone can be questioned. The results from the Fairty samples do not even overlap, making them less than acceptable. Fairty may still be associated with the Middleport Robb and/or Faraday sites. In either case, the people of Fairty were marginal horticulturalists, it is only the extent of their reliance upon maize which cannot be determined from dating methods alone.

#### ***Integrity of the Fairty Ossuary for Research Purposes***

All available evidence indicates that the Fairty ossuary was only superficially looted. Looters generally remove artifacts and/or complete adult skulls, leaving the rest of the collection intact (this of course depends upon the extent of the looting, and the damage caused by the looters). The excavation was accomplished in only six days by amateur archaeologists who were members of the Ontario Archaeological Society. The sample contains many small phalanges and fetal bones, suggesting that everything was collected. In addition, Anderson (1964) notes a total of 350 individuals represented by tali, and 394 represented by calcanei. There are 380 individuals represented by the second cervical vertebra. Assuming that this is a count of the complete bones only (they are the only ones which have catalogue numbers on them in the collection), there would be an increased MNI when portions of these bones were also counted. On average, approximately 120 individuals are unaccounted for by counts on these bones (MNI =

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<sup>3</sup> The Bennett Site is a village site containing only single primary burials. Its placement into the Pickering branch is questioned by at least one researcher, who feels that it is Uren (Burse 1994).

512). This is a good representation of small bones of the skeleton, further suggesting that the excavation was thorough. The numbers of these bones are similar, and if it is assumed that they were generally left behind when a primary burial was excavated and made into a bundle for secondary interment in an ossuary, then there may have been up to 120 bundle burials in the ossuary. Given that the excavation appears to have been thorough, it is puzzling that the bundle burial(s) were not excavated and retained as distinct features within the ossuary. This is vital information (complete individuals) which has been forever lost. As is demonstrated in Chapter 5, the number of juvenile mandibles and juvenile femora are nearly the same. This also suggests complete recovery of the remains.

The Fairty ossuary has been utilized by many researchers (Anderson 1964, 1968, Jackes 1986, Katzenberg 1992, Katzenberg and White 1979, Larocque 1991, Melbye 1984, Molto 1983, Ossenberg 1969, Patterson 1984, Stothers and Metress 1975, Sullivan 1988 and others). With the exception of the sectioned humeri and missing teeth, the sample appears to have remained largely intact in the years since its excavation. Those portions which were not in storage with the bulk of the material were easily retrievable from elsewhere in the University of Toronto's collections because they had been labeled.

### **The Kleinburg Ossuary**

#### ***Location and History***

The Kleinburg ossuary was located northeast of the town of Kleinburg on a tributary of the Humber river, in a farmer's field. It was excavated in the early 1970s by Dr. J. Melbye with a crew from the University of Toronto. The site was brought to the attention of Dr. Melbye by a student who lived on the property and who had brought human bones which had been plowed up to a professor at York University. Subsequently, the bones were brought to Dr. Melbye. A newspaper article was located which dated to the mid 1800s noting the opening of an ossuary in the area, and the removal of some bones (J. Melbye pers. com.)

The ossuary was approximately 4.2 m in diameter, and 1 m deep. Bones were recovered within the plow zone. The undisturbed portions of the feature indicated that the ossuary was circular with relatively vertical sides. A small “channel” containing mostly skulls projected off of one side of the pit. This channel was not as deep as the main ossuary pit. The excavation was done maintaining 5 foot square units, in arbitrary levels of 5 inches once the bones in the plow zone had been collected. The excavation “quartered” the ossuary, leaving criss-crossing baulks which showed a sterile soil layer running on an angle through part of the pit. This suggests that the ossuary was used on two separate occasions. Approximately one quarter of the ossuary had been disturbed from the top to almost the bottom, and it is thought that this had occurred in the 19th century, when as much as a quarter of the bones (skulls?) had been removed (J. Melbye pers. com.).

The ossuary contained partially articulated bodies on the floor, covered by disarticulated material in the upper layer. The skeletal material was arrayed in the pit in a random fashion, as a series of chi-square ( $X^2$ ) tests indicated (Pfeiffer 1980a). Four peripheral burials were found, one extended, one flexed, one bundle, and one a partial individual. The minimum number of extant individuals has been estimated at 561. Grave goods included the earliest known iron trade axes in Southern Ontario, an iron kettle, shell beads, native copper beads, and large glass trade beads. The artifacts date the ossuary to circa 1600 AD. It is likely that the inhabitants of the ossuary itself never came into direct contact with Europeans; rather, the European artifacts were traded to the interior before the arrival of Charnplain (J. Melbye pers. com., D. Knight pers. com.).

The Kleinburg ossuary has been stored at the University of Toronto at Mississauga, under the curation of Dr. J. Melbye since its excavation. It has been used for teaching purposes, and has been the focus of many analyses (Jackes 1977, 1986, Katzenberg 1992, Larocque 1991, Molto 1983, Patterson 1984, Pfeiffer 1980a, b, 1985, Pfeiffer and King 1983, Saunders and Melbye 1990, Sullivan 1988, and others). A complete report of the skeletal remains has not been published.

### ***Integrity of the Kleinburg Ossuary for Research Purposes***

The skeletal remains from the Kleinburg ossuary do not include the full complement of remains which were originally interred in the grave. Approximately one quarter of the remains are missing due to the ossuary opening in the mid-19th century. However, it may be assumed that it was primarily skulls that were removed (J. Melbye pers. com.). As the individuals were disarticulated and mixed, at least in the upper strata, the removal should have effected a random exclusion of skeletal parts. The bottom of the ossuary was undisturbed. In spite of the documented removal of remains from the ossuary, the number of juvenile mandibles and juvenile humeri are very similar (see Chapter 5), suggesting that the sample was subject to only random removal of elements, or removal of elements not considered here, such as adult skulls.

The post excavation storage of the remains has been in one location, although scattered throughout the various storage and study labs. The teeth have been carefully preserved in their sockets, and loose teeth have been sorted and stored. All long bones are intact with the exception of the left subadult femora which were sectioned for the 1990 study by Saunders and Melbye. These were, however, measured before destruction. The Kleinburg collection appears to be complete as excavated, and well maintained, but a very thorough search had to be made before all of the portions necessary were located. A careful search through teaching material must be done by any future researchers, as the collection continues to be used as a valuable teaching tool, and skeletal elements remain in various locations within the Anthropology Department at the University of Toronto at Mississauga.

### **The Carton Ossuary**

#### ***Location and History***

The Carton Site is located in Halton County near Highways 401 and 25. It consists of a village with an ossuary located approximately 100 metres to the north of it. The ossuary was first discovered in 1958 and excavated in 1967 and 1968. The first season of excavation yielded the information that the pit was 112 inches by 132 inches

and shallow. It was also located in proximity to a habitation site, which appears to have had a surface collection only. The ossuary yielded 8 skulls in 1958, and the bones are purported to have been badly plow damaged and buried in hard clay (Axelson nd.). Excavation was continued in 1967 and 1968 when skeletal material which is reported to have been in fairly good condition was removed with great difficulty from the surrounding clay matrix (Axelson 1970). It is estimated that 303 individuals were recovered from this ossuary (Yamaguchi pers. com. cited in Hartney 1978) The ossuary is dated to AD 1595 ± 15 years, based on artifact association (mostly beads) (Axelson 1970). This date falls within the Glass Bead Period 1 of the Early Fur Trade Neutral tribes (1580 to 1600 AD) (Lennox and Fitzgerald 1990:409, Fitzgerald 1990).

Various analyses of this ossuary are mentioned in some publications (see Hartney 1978, Molto 1983 and Patterson 1984). Neither of the following manuscripts could be located: Sundick, 1969, Winnicki, 1969. Hartney makes reference to a complete analysis of the material by Yamaguchi, but no manuscript has been located. Some undergraduate student papers are in the archives of the University of Toronto, Department of Anthropology. Sundick (1969) sectioned all of the osteitic long bones, but left behind no record of measurements of these bones before their destruction (Hartney 1978).

The ossuary appears to have remained in storage at the University of Toronto since its excavation. Some elements were found in the teaching collection of the St. George campus, and returned to the larger storage boxes. It is complete except for some small bones which have jewelry still associated with them, and are in possession of the excavator (Axelson 1991 pers. com.). The artifacts are not stored with the ossuary. Apparently notes and drawings of the excavation are in the personal file of the excavator (Axelson pers. com.). A request by this writer to examine these materials was met with resistance by Mr. Axelson. He cited the failure of other researchers to provide him with copies of their research results as his reason for not being forthcoming with any aid.

### ***Integrity of the Carton Ossuary for Research Purposes***

The ossuary had first been discovered in 1958, when it was already plow damaged, and, therefore, exposed to any observer, then opened in 1967, then closed, then opened in 1968. It is unknown whether any clandestine digging took place between the field seasons in 1958, 1967 and 1968. The bones themselves are considerably damaged by shovel/plow marks and show sun-bleaching from surface exposure. The bones are extremely eroded, due to both burial in a hard clay matrix, and exposure to the elements. In soil conditions such as these, one may expect that more fragile bones would not survive as well. The ossuary was excavated by an amateur, suggesting that the recovery of all material may not have been complete. It is quite common for persons with little or no osteological/archaeological experience to assume that only the complete, or “big” pieces have any research merit. Very few small fragments or portions were found in the “unanalyzable” boxes. The contents of these boxes appear more similar to bones left behind when processing bone directly from the field, than actual small fragments excavated from the feature itself. Most of these small fragments were the result of recent breakage or damage. This, of course, may indicate that whomever attempted a complete analysis of the material identified and separated every small element or portion thereof. This is most unlikely.

The combination of a potentially erosive burial matrix, probable clandestine digging, and excavation by an amateur should throw the overall integrity of this ossuary as containing all or most of the remains which were interred into it grave doubt. It is also only presumed that the ossuary was fully excavated, and that there is no way of assessing what bone material may have been lost over countless years of plowing the top layers. In the case of this ossuary, it is almost certain that the remains of infants and children would have been lost post-interment, had they been originally present. The dental remains were, however, well preserved and the minimum number of individuals large (as noted by Yamaguchi pers. com. cited in Hartney 1978). In addition, this research assumed at the outset, that element removal by clandestine activity from any feature being researched would have been either random, or specifically geared towards collecting adult skulls. The results of a count of juvenile mandibles and femora from this site show that the

numbers are very similar, suggesting no bias in preservation or non-preservation of elements (see Chapter 5).

## **The Milton Site**

### ***Location and History***

The Milton Site is located in Halton County, approximately 3 miles north of the Carton Site, and 7 miles south of the Glen Williams ossuary. The site consisted of a habitation area, a main ossuary surrounded by 4 small burial pits located 200 metres southeast of the habitation area (Milton ossuary #1, or AjGx - 2), and another ossuary (AjGx - 8) located 150 metres to the north of the village. AjGx - 8, also known as the McClellahan ossuary or Milton ossuary # 2 has been suggested to be contemporary with the habitation area (Glass Bead period 1, 1580 - 1600 AD.) (Fitzgerald 1990). Ossuary #2 was 7 feet, 6 inches in diameter and 11 inches deep. The excavators suggest that it was originally 19 inches deep before plowing and looting, by creating an hypothesized ground line (from the extant edges of the pit). A minimum number of 11 individuals (8 adults and 3 juveniles) is presented in a preliminary analysis of the remains (Reid and Conway 1976). The excavators note a small sub-floor pit in the ossuary which contained a "bundle burial". The photos and description of the remains within this small pit are not suggestive of a bundle burial in the classic sense; rather it appear to be a sub-floor pit containing disarticulated bone with no association, not unlike the typical mixed bone assemblage seen in other ossuaries. The excavators note that this small pit appeared to be the only portion of the ossuary which was undisturbed (Reid and Conway 1976).

Ossuary #1 was presumably totally excavated in 1966, and yielded approximately 109 individuals. It measured ca. 3 metres in diameter and was approximately 1 metre deep. The ossuary is said to have been robbed at least twice prior to the excavation, "leaving the quality of the bones in bad condition, but the quantity probably not affected" (Hartney 1978:128). The ossuary is dated to the 17th century, and is probably historic Neutral in tribal affiliation (Hartney 1978:table 1, Reid and Conway 1976). Attempts to date the Milton ossuary #1 by glass bead sequence met with failure when the beads could not be located (Fitzgerald 1990:276). The Milton village site itself has been assigned to

the prehistoric period, although Fitzgerald does not accept this theory, because of the proximity of the village to Glass Bead Period 1 Ossuary #2. Additionally, he states that the village was dated as prehistoric because no trade goods were recovered. A lack of trade goods from the village site does not necessarily imply that it is prehistoric, because there is an overall infrequency of European goods in the area (1990:276).

The Milton ossuary #1 was stored at the University of Toronto for some time after its excavation. At some point in the 1970s, it was moved to the University of Saskatchewan. The only analysis ever undertaken on the remains is by Hartney (1978). The ossuary was returned to the University of Toronto in the early 1990s, presumably complete. It is apparent that many analyses were undertaken on the remains, as a good number of bones have been sectioned or otherwise damaged. No publications have been printed, and no data has been found from these studies. The artifacts are not stored with the ossuary. The ossuary is currently being fully analyzed by Bonnie Glencross. Milton Ossuary #2 has only been preliminarily analyzed (Reid and Conway 1976).

### ***Integrity of the Milton Ossuary for Research Purposes***

The preservation, as Hartney (1978) noted, is not good. Post-mortem shovel trauma and erosion are much in evidence, and many of the bones are incomplete.

The ossuary has journeyed half way across the country and back, and the artifacts were left somewhere along the way. More disturbing for skeletal studies is that the most recent analysis of the material determined the MNI to be 44 adults, and 42 subadults (N = 86) (B. Glencross pers. com.). This is less than the 109 individuals noted earlier by Hartney (1978:193). In general, comparisons of counts between each bone of the skeleton yielded a lower number in the Glencross study than the Hartney study. Extreme care was taken to thoroughly search all of the boxes which were returned from Saskatchewan in order to ensure that none of the Milton material was inadvertently packed with the Glen Williams material.

Hartney noted of the thousands of bone fragments processed, "Although they are generally badly damaged, it would appear that little was actually removed prior to 1966"

(1978:128-129). His own bone counts give a different story, varying as widely as 109 for the ulnae, to 41 maxillae, and 72 mandibles. This suggests that the quantity was affected by the clandestine activity (contrary to Hartney's statement above). The counts are further decreased since the return of the ossuary material to the Department of Anthropology's collection. It must be assumed that there will be many problems in any attempt to analyze this site and propose sample or population frequencies.

### **The Issue of Cultural Bias and Ossuary Samples**

Brébeuf, in his 1636 relation noted that if an infant less than a month or two old died, it was buried near a road, so that its spirit could be reborn through another woman's womb (Thwaites 1896-1901). This single ethnohistoric reference has been cited as justification for correcting infant under-representation in many Native Ontario skeletal samples in the past decades. Brothwell (1971) noted that infants could be expected to be underrepresented in skeletal samples, whether by poor preservation, or by exclusion due to cultural practices. Melbye (1977), and Sullivan and Melbye (1978) first proposed that an infant correction factor be added to ossuary samples in order to make them more representative of the living population for palaeodemographic studies. Researchers continued to utilize the infant correction factor, whether it was an equation applied to the data, or by comparison to model life tables to adjust the number of infants in Southern Ontario ossuary samples (Jackes 1986, Katzenberg and White 1979, Sullivan 1988). Melbye (1984) noted that the infant correction formulae were likely not valid for Iroquoian samples. This was based upon a re-working of Anderson's (1964) ages for the Fairty sample, and discovering that in fact, an acceptable number of infants are represented in the sample.

It is the contention here that it is most likely that most ossuary samples are not representative enough for palaeodemographic reconstruction, but that inferences about subadult health can be made if enough subadults are present to provide large enough sub-samples for each age cohort for inter-sample comparison. There is no doubt that ossuary samples are culturally biased. Some infants were probably disposed of in the manner mentioned by Brébeuf. In addition, other sources state that differential burial practices

were followed for individuals who died in warfare, by drowning, or by suicide (Thwaites 1896-1901; Brébeuf 1636:146:182, Bressani 1653:32). Death by violence and from exposure to the cold precluded that the individual would be disinterred for reburial in the ossuary (Thwaites 1896-1901; Bressani 1653:31. It has also been stated that the very old and the very young were not removed from their primary graves for re-interment in the ossuary because it was thought that they did not have the strength to travel to the land of the souls (Thwaites 1896-1901; Brébeuf 1636:143). Extensive archaeological work has shown that by no means were all individuals excavated to be re-interred in ossuaries. Most villages contain burials in the house floors, and elsewhere in the village vicinity. It should be questioned whether the Feast of the Dead described by Brébeuf for the Ossossané ossuary was the norm, or rather a tradition much modified by the political pressures placed upon the Huron at the time, including, as it did, the dead from many and scattered tribes. Even if it is accepted as representative of all Feasts of the Dead that went before it, it must be asked - for how long before 1636 was this a practice, and just who was interred in the ossuary? Large ossuaries are not the most common mortuary practice in any of the Iroquoian cultural stages.

Each ossuary sample must be carefully evaluated on its own. If there is not 30 to 50% subadult mortality, with the bulk of the subadults in the 0 to 1 year age category, then the ossuary sample should not be expected to be representative of the living population. This rate of juvenile mortality is to be expected in any pre-antibiotic population sample. The sample may, however, be representative of the dead at any given time. It appears from the ethnohistoric accounts that few were excluded from the ossuary. The comment about the old and young being excluded is patently not true, as both of these age groups have been found in ossuary samples. Exclusion may have been an occasional rather than general tenet. From the careful evaluation of the skeletal material from the ossuaries utilized for this study, it is apparent that environmental bias in the form of robbing the graves and mis-handling by some researchers post-excavation has contributed more to the loss of data than any cultural bias. Of course, this is one thing of which we can never be sure. Environmental bias in terms of preservation really not an issue if individuals are trained to excavate thoroughly, or if individuals trained to excavate bones were responsible for the excavation. This is not always true of the extant

ossuary samples, but each must be evaluated for clues from both the evidence of field notes and photos, and from the bones themselves.

An attempt has been made with each of the samples studied here to thoroughly document the potential for environmental bias. Cultural bias has been briefly addressed here, and is considered in more detail in Chapter 6. Any researcher attempting to analyze these samples must be aware of the potential limitations of each specific sample for questions concerning the living populations from which they derived. If infants are underrepresented in a sample, it may suggest that other age groups are similarly underrepresented as well.

# CHAPTER 4

## *Methodology*

### **General Methodology**

Data collection followed three stages for each of the sites discussed in Chapter 3. Each of the skeletal samples was curated differently so that the data collection methodology differs somewhat for each. Data collection stage 1 involved thoroughly searching each collection for subadult femora and humeri. A number of measurements were taken from each bone in order to either provide a length by transformation of a diaphyseal end measurement, or by direct measurement of the diaphysis. These diaphyseal lengths were then utilized to provide an age at death for each specimen utilizing two sets of standards based upon population samples of known age at death.

Data collection involved culling all of the mandibles with dentition which were still in the calcifying stages (both permanent and deciduous). These mandibles were then radiographed in order to determine the age at death of each individual by dental calcification stages. All attempts to match mandible portions were made, both with the gross specimens and by comparing the developmental stages of sets of dentition in unpaired hemi-mandibles, or portions thereof shown by the radiographs. The ages at death derived from the long bones were compared to those derived from the dentition within each sample, both as a test of representativeness of the mandibles, and as a test of each age at death method utilized. The specific methodology utilized for each sample at each stage of data collection is detailed below.

### **The Fairty Ossuary**

#### ***Data Collection: Stage 1***

The skeletal remains from the Fairty ossuary are stored in approximately 90 boxes in the Department of Anthropology, University of Toronto. In addition, a number of bones were discovered in the teaching collection, display cases, in other locations, and at

the Royal Ontario Museum. All of these “scattered” remains were returned to the storage boxes, with the exception of some of the teaching material and the bones at the ROM. Those bones left in other locations were analyzed and replaced.

Approximately 8 boxes are labeled as “unanalyzed.” Each of these boxes was thoroughly searched for all juvenile material. This material was then removed and sorted into the appropriately labeled box (e.g., juvenile humeri, juvenile cranial fragments, etc.). This thorough search added many more complete and incomplete skeletal elements to the samples than were originally analyzed by Anderson (1964). All of the boxes containing Fairty remains were checked in order to ensure that no pertinent elements were missed. Where bones were discovered to be in the incorrect box, these were removed to the correct one.

All of the subadult humeri were laid out for analysis. Cross mends were made where possible, and each proximal, distal and midshaft portion was sided, and counted. Three measurements were taken on each complete bone: 1. Maximum length. 2. Maximum width of the distal end. 3. Maximum width of the proximal end (see Appendix 1). The bones that were represented by a single end only were measured by the appropriate measurement, as stated above. A minimum number of individuals was derived from the most numerous represented portion of the humeri. All values of the measurable humeri were entered into a database for statistical manipulation. A count of the non-measurable humeri was kept to be factored in an overall assessment of the minimum number of individuals represented by the bone.

The same procedure was followed for the femora, with three measurements being taken on each complete bone (see Appendix 1), and appropriate measurements being taken on incomplete bones.

Pearson Correlation coefficients were calculated in order to ensure that there was the expected relationship between the length of a long bone, and its maximum widths at each end. Linear regression analyses were then performed to assess the dependence of the widths at the ends of the bones on their lengths, and then to predict length from measurements of the widths at the ends of the bones. The long bone lengths were then

transformed into ages using the data of Merchant and Ubelaker (1977), and the data of Maresh (1955). The results of this transformation provide a mortality curve for all of the left subadult femora in the sample, using complete lengths and lengths predicted from the proximal breadth.

### ***Data Collection: Stage 2***

The mandibles from the Fairty ossuary were surveyed, and all of those which had calcifying dentition, up to and including the third permanent molar, were culled. The mandibles were taken to the x-ray facilities at the morgue, Office of the Chief Coroner, Toronto. X-rays were done using normal Kodak film, with a focal distance of 108 cm, and exposed for .06 seconds at 4 mAs and 60 KV. by a trained x-ray technologist (Ms. B. Bulgar or Mr. B. Blenkinsop). For the most part, the Fairty mandibles were hemi-mandibles only, many of which displayed evidence of recent breakage at the midline. This facilitated the taking of x-rays. In the cases where the mandibles were complete, two x-rays were taken of each mandible, in order to show the full complement of unerupted dentition. Age at death was determined by scoring the dental calcification stage and/or the root resorption stage following the method of Moorrees et al. (1963a, b). Prior to calculating the final age, the hemi-mandibles were matched with their mates, first by gross observation, and then by comparing dental development on the x-rays. The hemi-mandibles with extant and complete mentons that remained, whether from the right or left side of the mandible, were considered to represent a unique individual.

The age at death for each individual was calculated by scoring each tooth present, interpolating the age from the plots of Moorrees et al. (1963a, b) for both female and male, and entering all of these ages, by tooth into a data base. The mean age for each mandible was then calculated by sex, and the mean of the ages for both sexes was taken as the final age. A matrix of Spearman Correlation coefficients was derived, and carefully assessed to determine if any of the teeth were consistently giving a different age than others in each mandible. A final age was derived for each mandible with only those teeth which were predicting a similar age. A number of hemi-mandibles contained no teeth, the large crypts having allowed post-mortem loss of the developing crowns. These

mandibles all derived from individuals in which the hemi-mandibles had not yet fused. In order to complete the database, each of these was assigned an age of 6 months, and entered into the dental age database. Recognizing that they were of course not all 6 months of age, they were at least less than one year, and would be represented as such in graphic or statistical output, because they would all end up in the same cohort (0 to 9 months).

The final step in this data collection stage was to produce a mortality curve based on the ages at death from the mandibles. The Student's T-test was applied to the samples of ages derived from the long bones and from the mandibles. This test was necessary to demonstrate that the mandibles and long bones were derived from the same group of individuals, and to test the concordance of the three different aging methods used. Finally, a sub-sample of each of the long bone aged samples and the dental aged samples were randomly chosen from the database. These were plotted with mean age and age range in order to assess if the actual range of ages was greater than the age difference observed between the two methods. This was to control for possible methodological bias.

## **The Kleinburg Ossuary**

### ***Data Collection Stage 1***

The Kleinburg ossuary is stored in a number of different rooms in the labs of the University of Toronto at Mississauga. This ossuary was excavated and studied utilizing scientific methods, and it was, therefore, expected that the various boxes labeled as to their contents would contain all of those bones. In other words, that the "unanalyzable" material would be really that. For this reason, no effort was made to thoroughly search the fragment boxes. The humeri, femora and tibiae were removed and measured and transformed in the same way as described for Fairty. The long bones from this ossuary were measured by myself and another observer. This was done in order to ensure that the measurements were reproducible. Statistical tests (T-tests) were performed to test inter-observer error.

The lengths of the right humeri (derived from complete humeri and transformed proximal end breadths) were then transformed into age at death utilizing the standards of Merchant and Ubelaker (1977), and Maresh (1955). These ages were used for comparison with the dentally derived ages.

### ***Data Collection Stage 2***

This stage of data collection followed the methodology outlined for the Fairty ossuary above. An additional step was done with the dental ages from Kleinburg. The ages were compared to the published ages derived from two independent studies (Sullivan 1988, Saunders and Melbye 1990), as a test of interobserver error.

### **The Carton Ossuary**

#### ***Data Collection Stage 1***

The first stage of data collection for this ossuary was similar to that of Fairty. Bones which were found in the teaching collection were returned to the storage room. All boxes were searched, and the unanalyzable boxes were thoroughly searched. All juvenile humeri and femora were removed, cross-mends were made, and measurements taken as described above. The regression equations derived from the combined Fairty and Kleinburg samples were applied to the incomplete bones from the Carton ossuary in order to transform them into total lengths. The sample size was too small to allow for derivation of within-sample equations. The lengths of the right humeri and the lengths derived from the proximal end breadths were then transformed into ages utilizing the data of Merchant and Ubelaker (1977), and Maresh (1955).

#### ***Data Collection Stage 2***

Data for this stage was collected in the same manner as that of the Fairty ossuary.

Manipulation of the data was done in the same manner as that of the Fairty and Kleinburg samples, on both the Carton ages separately, and the Carton and Milton ages combined.

## **The Milton Ossuary**

### ***Data Collection Stage 1***

This sample was being analyzed by Ms. Bonnie Glencross at the time that data were being taken. This writer assisted Ms. Glencross in sorting some of the material, in particular the fragments. Ms. Glencross performed the diaphyseal breadth and length measurement after Hoppa and Gruspier (1996), after this writer had illustrated the proper technique. Measurements of the femora only were then provided by Ms. Glencross. The measurements of the complete left humeri and predicted lengths from the proximal end breadths were transformed into age at death using the standards of Merchant and Ubelaker (1977) and Maresh (1955).

### ***Data Collection Stage 2***

Ms. Glencross provided this writer access to the dental material, and all of the subadult mandibles were removed and radiographed as per the method outlined above for the Fairty, Kleinburg and Carton mandibles.

The data from the Milton long bones and dentition were analyzed both combined with the Carton material, and separately, in the manner described for the Fairty remains, above.

# CHAPTER 5

## *Results and Discussion*

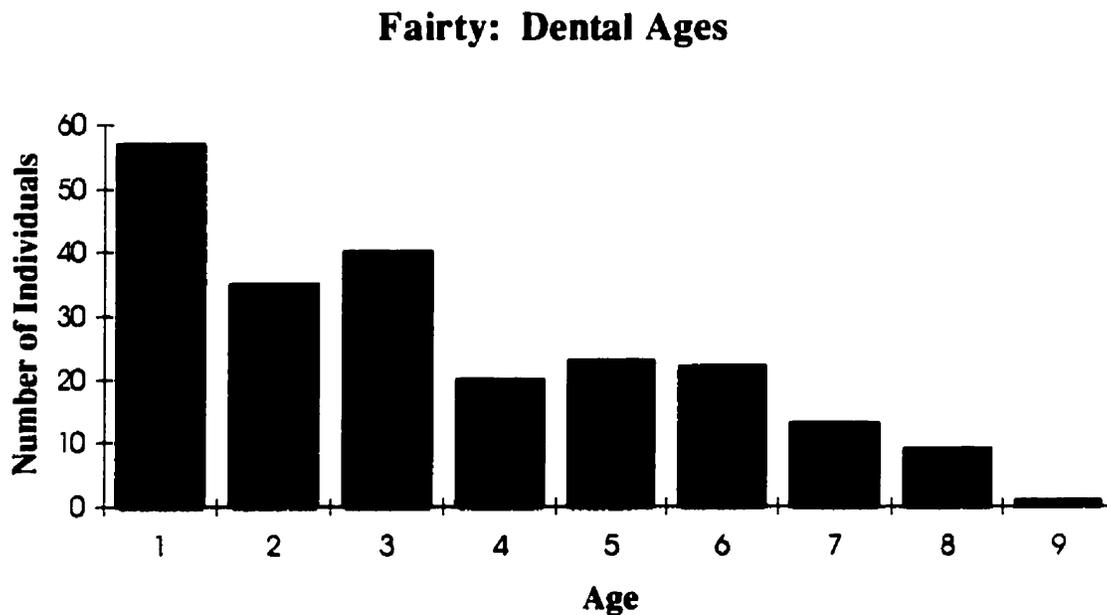
### **The Fairty Ossuary**

#### ***The Teeth***

In order to acquire a complete database, all juvenile mandibles were retrieved from the Fairty remains. Prior to radiographing, the mandible portions were searched for cross mends, and these were made in order to provide as much age information as possible for any one individual. Further cross-mends were accomplished after radiography by comparison of dental root morphology, dental development, and cancellous bone structure of mandible portions. Each tooth was then given a dental calcification score by comparing the crown or root development with the Moorrees et al. (1963a, b) standard drawings. Mean ages of attainment for each stage were calculated from the original publications. Other researchers have published mean stages of attainment, but upon close scrutiny, these standards were found to be inconsistent with one another, and in some cases to contain outright errors (Steele and Bramblett 1988, Smith 1991). Each tooth was scored once by the male standards, and once by the female standards. In most cases this resulted in a total of two scores per tooth, except for the first permanent incisor, for which no score for root  $\frac{1}{4}$  was available for the males. These scores were entered into a database for statistical manipulation utilizing Systat and SPSS. No scores of apex complete were entered, as this stage represents completion of formation only. Any tooth scored at that stage could have been that age or older. This was true of both the deciduous and permanent dentition. Resorption ages for the deciduous molars were recorded. All teeth but the permanent third molars were recorded. Third molar development is highly variable, and any individuals this old may had their epiphyses fused to their diaphyses, making a comparison between the ages derived from diaphyseal length and dental development impossible.

The total number of teeth scored for the Fairty ossuary was 1366 in 170 mandibles or portions of mandibles.

Each mandible or portion thereof was assigned an age by calculating the mean age from all teeth scored in that mandible, by the standards for each sex. Sex determination from subadult skeletal material is generally considered to be imprecise when one has a complete skeleton to analyze, and impossible with only mandibles or mandible fragments. Most researchers combine the sex-specific results of any age standards method when applying it to an archaeological sample. That practice was followed for this sample, and an average age of attainment was produced for each case. The results of the age determination for the Fairty sample is seen in Figure 1 below. This graph also contains 50 individuals which were represented by infant hemi-mandibles with no extant teeth. These hemi-mandibles were aged 0 to .9 years, with a mean age of 0.5 years for each. The two halves of the mandible fuse at 1 year.



*Figure 1: Histogram of mean dental ages for the Fairty ossuary sample.*

The graph clearly shows that there is an abundance of individuals in the 0 to 1 year category, and a peak again in the 2 to 3 year category. The ages at death determined by dental calcification are not normally distributed.

The dental calcification standards provided by Moorrees et al. (1963a,b) were taken from radiographs of North American living White children who were followed in a longitudinal study. Different teeth within one mandible will show a different stage of development (e.g. root complete, crown complete, crown ½ etc.). All of the tooth stages are linked by virtue of occurring at the same age. Research has suggested that stages of calcification may differ for modern Native and Inuit children (Trodden 1982). If this is the case, it is possible that there may be underlying genetic factors causing these deviations from the modern White North American norm. It follows that these deviations may also have been present in Native prehistoric and historic populations. Spearman Correlation Coefficients were generated in order to test if any teeth within the mandibles of the Fairty subadults were predicting significantly different ages than the associated teeth within a mandible. This would indicate that those teeth were exhibiting different calcification standards from the reference sample. The Spearman Correlation Coefficient<sup>4</sup> was generated for each tooth by each other tooth in the mouth, controlling for side and sex. The average age results compared to each tooth are presented in Table 4 below.

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<sup>4</sup> The majority of statistical tests chosen for this research are parametric. Although the data does not appear to be normally distributed (dental or diaphyseal), the sample is large enough so that the central limit theorem can be applied (Sokol and Rohlf 1995). In the case of the dental correlation test, both Pearson's and Spearman's product moment correlation tests were applied. The Pearson's assumes bivariate normality which is not demonstrated without the application of the central limit theorem here, so in order to err on the side of conservativeness, the Spearman's is presented here. Of the non-parametric coefficients, Spearman's is best used when there is less certainty about the reliability of close ranks, and therefore is more conservative than Kendall's  $\tau$  (Sokol and Rohlf 1995:600). The results of both the Pearson's and Spearman's coefficients for all teeth were done, and the results are essentially the same.

Tooth		Mean Age Female	Mean Age Male	Mean Age Sexes Combined
Left first deciduous molar	$r_s$ N	.921 *** (25)	.914 *** (23)	.918 *** (25)
Right first deciduous molar	$r_s$ N	.925 *** (25)	.853 *** (24)	.919 *** (25)
Left second deciduous molar	$r_s$ N	.872 *** (42)	.878 *** (41)	.878 *** (42)
Right second deciduous molar	$r_s$ N	.891 *** (35)	.923 *** (39)	.912 *** (39)
Left first permanent incisor	$r_s$ N	.414 <sup>ns</sup> (9)	insufficient data (2)	.414 <sup>ns</sup> (9)
Right first permanent incisor	$r_s$ N	.089 <sup>ns</sup> (13)	insufficient data (4)	.223 <sup>ns</sup> (13)
Left second permanent incisor	$r_s$ N	.905 *** (10)	.900 *** (11)	.929 *** (11)
Right second permanent incisor	$r_s$ N	.649 * (10)	.783 ** (9)	.649 * (10)
Left permanent canine	$r_s$ N	.934 *** (68)	.937 *** (54)	.940 *** (68)
Right permanent canine	$r_s$ N	.939 *** (54)	.947 *** (54)	.946 *** (54)
Left permanent first premolar	$r_s$ N	.953 *** (64)	.967 *** (63)	.951 *** (64)
Right permanent first premolar	$r_s$ N	.949 *** (73)	.960 *** (74)	.959 *** (74)
Left permanent second premolar	$r_s$ N	.935 *** (44)	.939 *** (42)	.936 *** (44)
Right permanent second premolar	$r_s$ N	.957 *** (49)	.820 *** (50)	.958 *** (49)
Left permanent first molar	$r_s$ N	.951 *** (53)	.941 *** (54)	.949 *** (53)
Right permanent first molar	$r_s$ N	.969 *** (60)	.968 *** (60)	.968 *** (60)
Left permanent second molar	$r_s$ N	.860 *** (27)	.909 *** (23)	.882 *** (27)
Right permanent second molar	$r_s$ N	.793 *** (30)	.820 *** (33)	.827 *** (33)

ns = not significant

\*  $P \leq 0.05$

\*\*  $P \leq 0.01$

\*\*\*  $P \leq 0.001$

Table 4: Spearman Correlation Coefficient results for the Fairty dental sample; each tooth by mean for sex, and sexes combined.

The correlation between separate teeth and the mean ages both by sex and for combined sexes is generally high. This is to be expected, as the ages from each tooth

contributed to the means. The correlation between the same teeth on opposite sides of a mandible (not presented here), generally approach near perfect correlation in age prediction. This is no doubt reflecting the biological reality, but also serves to suggest that scoring methods are homogeneous, particularly with the single rooted teeth where stage of calcification can sometimes be difficult to discern.

The correlation between most teeth and the mean ages by sex and for combined sexes is significant beyond  $p = 0.001$ . This high level of significance is also seen in correlation between single teeth and all other single teeth within any given mandible. The results of the correlation between the first incisors and the mean ages by sex and combined differ from the other teeth in producing a non-significant correlation. Spearman Correlation Coefficients run between left and right first incisors and the other separate teeth produce similar non-significant results. The first incisor scores derived from the male standards are non-existent owing to insufficient numbers. This is partly due to the fact that there are no comparative standards for development until the tooth reaches the "root  $\frac{1}{2}$ " stage, by which time the tooth crypt is open enough to allow the tooth to fall out, thereby accounting for a lack of central incisors in the 5 year plus ages. There are more incisor ages included in the results for the female ages, as the tooth can be aged when the root is  $\frac{1}{4}$  calcified, and still held into the mandible by a virtually enclosed crypt. The correlation for the female standards is however also not significant. The sample sizes for both sexes are very small. In almost all of the cases, the age predicted by the central incisor is older than that of the mean age. The results of the correlation for the second incisors present varying levels of significance for both male and female standards. The sample sizes continue to be low however, and the correlation between the second incisor and other specific teeth is generally not significant.

Other researchers have noticed a similar trend with the incisors predicting non-comparable ages to those of other teeth, and explain the problem by the biasing effect of the sample. The incisor data was not collected from birth, and the incisor standards (both maxillary and mandibular) were collected from a different sample of children than that of the other teeth (Saunders et al. 1993, Saunders and Hoppa 1992).

The non-significant correlation of the incisor ages from the mean ages strongly suggests that these teeth should not be used for predicting age from Southern Ontario Iroquoian samples. Even if sample size is the major factor in biasing the results presented here, it is doubtful that any sample will be large enough to warrant their inclusion due to the likely early loss of the tooth for reasons stated above. It also underlines the probability that the age information having been collected from a different sample of children, not followed from birth has had a biasing effect on the prediction capability of this tooth. The second incisor should also be considered suspect for predicting age at death. The small sample size in this research make it impossible to test the utility of this tooth as a predictor of true age.

A mean age at death for each set of dentition had been calculated by averaging the results of all ages from all teeth in a particular mandible by sex. The mean results by sex were then averaged to give a final age determination. When the results of the Spearman Correlation indicated that the incisors were predicting significantly different ages than the rest of the teeth in a mandible, the mean ages were recalculated, omitting the ages contributed by the incisors for any mandibles which had them scored. A plot of the two sets of ages was generated (Figure 2). In the majority of cases, the inclusion of the incisors resulted in a higher mean age estimate. Although this higher mean estimate was negligible, the incisors were nonetheless omitted.

### Fairy Teeth: Ages with Incisors vs. Ages without Incisors.

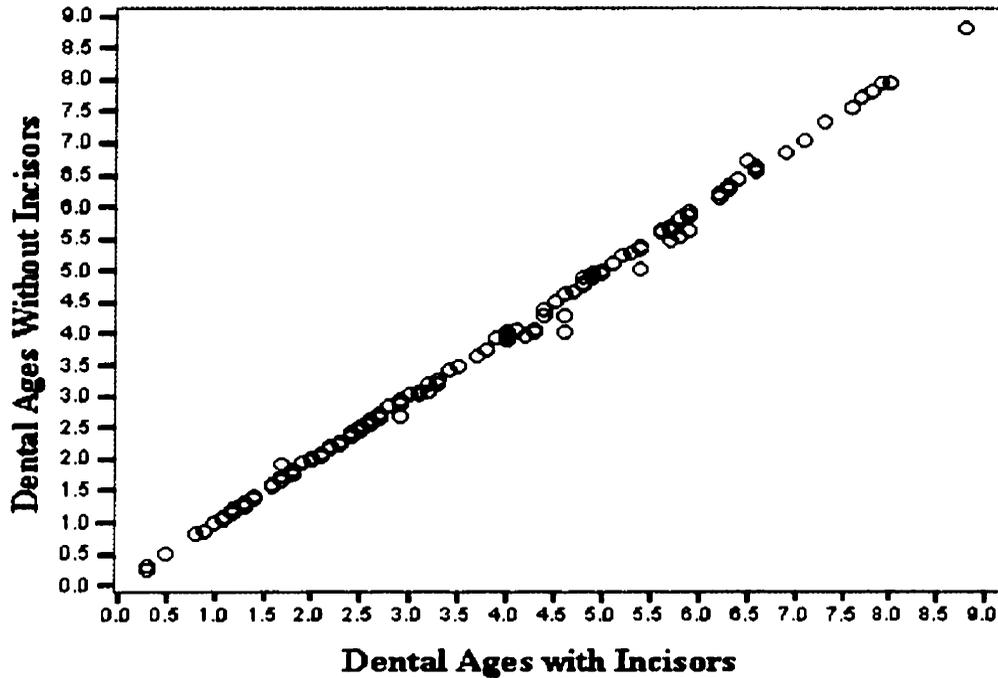


Figure 2: Scatterplot comparing the dental ages of the Fairy mandibles with and without the ages contributed by the central incisors.

### *The Long Bone Diaphyses*

The results of a thorough search of the Fairy juvenile material revealed many fragmentary specimens. Anderson (1964) had derived his highest MNI for juveniles from the humeri. The most data for estimating age from long bone diaphyses for the purposes of this analysis was from the femora. These elements were also found to be the best preserved. Time-consuming attempts at mending diaphyses to increase the sample of complete diaphyses available for measurement were not abundantly successful. It was postulated that there should be some relationship between the growth of the ends of the diaphysis (widths), and the length of the diaphysis. A literature search was not successful in revealing any studies that tested this hypothesis, although it appeared to be generally accepted. Measurements of all complete diaphyses for both the humeri and femora were

taken, as well as selected measurements (invented using anatomical landmarks) on the distal and proximal ends of the bones (see Appendix 1). Pearson Correlation Coefficients were calculated in order to determine if the diaphyseal length was indeed correlated with the width at either end of a diaphysis. The results are presented in Table 5 below.

	Diaphyseal Length	Proximal Breadth		Distal Breadth	
	N	N	r	N	r
Left Humerus	88	77	.9848	81	.9823
Right Humerus	90	82	.9858	86	.9838
Right and Left Humeri	178	159	.9854	167	.9830
Left Femur	90	70	.9912	69	.9813
Right Femur	86	64	.9872	57	.9721
Right and Left Femora	175	134	.9887	126	.9773

*Table 5: Results of Pearson Correlation Coefficients for the Fairy Humeri and Femora. Diaphyseal length versus proximal and distal end breadths.*

The results indicate that there is a very high degree of correlation between the length of the diaphysis and the breadths at the proximal and distal ends. All results in the above table are significant at  $p < 0.0001$ . The proximal femoral breadths exhibited the highest correlation with diaphyseal length, and they were the most numerous measurable portion present in the sample. A graphical presentation demonstrates the linear correlation between the diaphyseal length and the proximal end breadth (Figure 3).

### Fairy Femora:

### Proximal Width vs. Diaphyseal Length

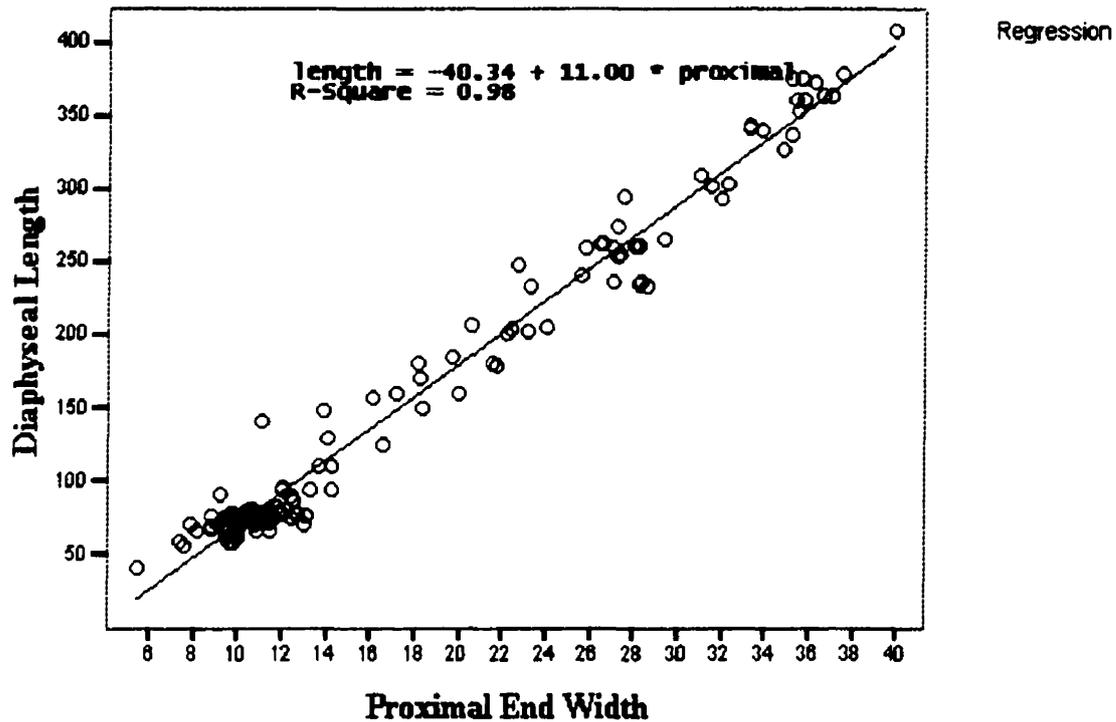


Figure 3: Scatterplot showing the relationship of the widths of the proximal end of the femora to the lengths of the femora for the Fairy ossuary. A linear regression line is superimposed over the data.

A linear regression model was applied to the data from both the right and left femora to derive a prediction equation for estimating diaphyseal length from the proximal end of the diaphysis. The results are presented in Table 6 below.

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Dependent Variable: LENGTH    Number:    136

Multiple R:    0.989

Squared Multiple R:    0.978

Adjusted Squared Multiple R:    .978

Standard Error of the Estimate:    15.524

Variable	Coefficient	Std. Error	Std. Coef.	Tolerance	T	P(2 tail)
Constant	-40.337	2.801	0.000	.	-14.399	0.000
Proximal	10.996	0.143	0.989	1.000	76.799	0.000

ANALYSIS OF VARIANCE

Source	Sum-of-Squares	DF	Mean-Square	F-Ratio	P
Regression	1421457.214	1	1421457.214	5898.068	0.000
Residual	32294.521	134	241.004		

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Table 6: Results of a Linear Regression analysis comparing the Fairty femoral lengths to the proximal end widths.

The equation derived from the linear regression model [- 40.337 + 10.996 (proximal breadth)] was applied to the 65 left proximal femoral measurements, and estimated diaphyseal lengths were obtained. This resulted in a total of 155 juveniles represented by left femora (the highest MNI which could be obtained from humeral or femoral measurements). At the time this data was being collected and tested, discussions with a colleague revealed that he had assumed the same relationship between diaphyseal length and diaphyseal end breadths while writing his Master's thesis (Hoppa 1991). Data derived from this study and measurements from the Kleinburg diaphyses (discussed below) were utilized to construct a new demography for the Fairty ossuary, and test inter-

observer error of the measurements. The results of this study were presented and then published (Hoppa and Gruspier 1996) (see Appendix 1).

The diaphyseal lengths, both true and estimated, for the left femora were transformed into ages at death utilizing both the data of Merchant and Ubelaker (1977) and Maresh (1955). The Merchant and Ubelaker standards were derived from a sample of Arikara skeletons, aged by dental calcification and eruption, and are not sex-specific, due to the inability to sex subadult skeletal remains. These standards are considered to have derived from a population more closely related genetically to the Fairty people, and to have undergone similar stresses during their lifetimes. The Maresh standards are derived from a longitudinal radiographic study of Colorado white children. The study is longitudinal in a sense, but none of the children were studied for their full period of growth, instead the authors present 3 groups of children; infants to 3-4 years, 3-4 years to 9-11 years and 9-11 years to 16-18 years. The results are presented by sex. It was thought that the Maresh standards would more closely compare to the dental ages calculated for the Fairty sample by the method of Moorrees et al. (1963a, b), as they both derive from modern white populations.

Determination of age is always presented as a range, or a mean and standard deviation. For purposes of statistical analysis, a mean age must be derived. In order to derive a mean age from the reference population of Merchant and Ubelaker (1977), the diaphyseal length means were compared to the Fairty lengths, and the closest mean length determined the age range into which the bone fit. The mean for the age range was then used in further statistical analysis. The age estimations for the diaphyseal lengths of the femora are presented in Figure 4 below.

## Fairty Femora Ages



Figure 4: Bar graph of age determinations of the Fairty juvenile femora by the methods of Maresh (1955), and Merchant and Ubelaker (1977) = Arikara.

The problem encountered with utilizing the Merchant and Ubelaker (1977) standards is that of missing data. Any femur less than 62.5 mm falls into the pre-birth category, which has no interpretive standards. This was true of only one individual with a femur length of 41 mm. This individual was mostly likely a fetal death, but in terms of demographic reconstruction, the pregnancy would have had all of the same effects on fertility and other maternal problems as birthing a live child, so the individual was included in the 0-1 year category. A more serious problem was encountered with some of the older age groups. There is no reference at all for the 8.5 to 9.5 age group. It is however bounded by two age groups with data and a non-overlapping range for each. All diaphyses which fell between 300.5 and 320.0 mm were assigned an age of 9 years. There is also no data for the 12.5 to 13.5 range, 13.5 to 14.5 range, 15.5 to 16.5 range and 16.5 to 17.5 range, although age ranges on either side and in the middle do have some interpretive standards. For these ranges, ages had to be assigned arbitrarily, based upon

the measurement's nearness to either the upper or lower age range in the pair. Few individuals actually fell into these categories, perhaps reflecting a good survival rate through the puberty years as also seen in the reference sample.

Maresh (1955) presents a mean age for a range of measurements. The diaphyseal length of each of the femora was compared to the 50th percentile value, and the closest age was chosen. Each diaphysis was assigned an estimated age for both male and female, and the two values were averaged to produce a mean age for the femur.

The least diaphyseal length presented by Maresh (1955) is 72 mm. Any diaphysis less than that length was assigned an age of .2 years, or about 2 months. This was the youngest age of subjects included in the original study. This is not a serious problem for later age comparisons, as any individual would fit into the broad category of 0 to 1 year. It is certain that some of the individuals in the Fairty sample would be aged less than birth by this method, but since there is no reference data, they cannot be identified. A more serious problem arises in the later age groups. Beginning at 12 years of age, the reference measurements include the epiphyses, making any comparison impossible, as only the diaphyses were measured in the Fairty sample. All individuals with a diaphyseal length of 384 mm or more were allocated into the 12 year age category.

In order to determine if the ages derived from the Merchant and Ubelaker (1977) and Maresh (1955) standards were similar, a Paired Samples T- test<sup>5</sup> was applied to the diaphyseal lengths transformed into ages by each method. The results are presented in Table 7 below.

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<sup>5</sup> The T-test only assumes that the differences between the means of the two data sets are approximately normal when they are small. This assumption becomes less critical when the value of n increases (Rees 1985).

**Paired Samples T-Test on Merchant and Ubelaker (1977) Estimated Ages vs.  
Maresh (1955) Estimated Ages  
With 155 Cases**

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MEAN DIFFERENCE =	0.645
SD DIFFERENCE =	1.317
T = 6.098	DF = 154
p = 0.000	

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*Table 7: Paired samples T-test comparing the means of ages derived from the Fairty femora using the methods of Maresh (1955) and Merchant and Ubelaker (1977).*

The result of the T-test is significant beyond the 0.001 level. This suggests that the methods are predicting different ages from the same bones. The mean difference between methods is more than half a year (0.645), with a large standard error of 1.317 years. Some of this error may be caused by including the non-comparable older age groups (recall that any individual over 12 years is aged as 12 years by the Maresh 1955 method). A subsample of individuals less than 12 years of age by both methods was selected and the T-test was re-calculated . The results are presented in Table 8 below.

The selection of a sub-sample of individuals less than 12 years of age continues to be significantly different. The sample size remains large, and the test is acceptable. Despite the significant differences in age determination from each method, the actual mean difference is much less; only 0.282 years, with a standard deviation of 0.441 years. The mean difference is calculated from all the comparisons of means for each pair. In order to clarify how many individuals are contributing to this mean difference, a graphic presentation of the mean differences between the two samples of ages less than 12 years is presented below (Figure 5)

**Paired Samples T-Test on Merchant and Ubelaker (1977) Estimated Ages vs.  
Maresh (1955) Estimated Ages Less than 12 Years  
With 142 Cases**

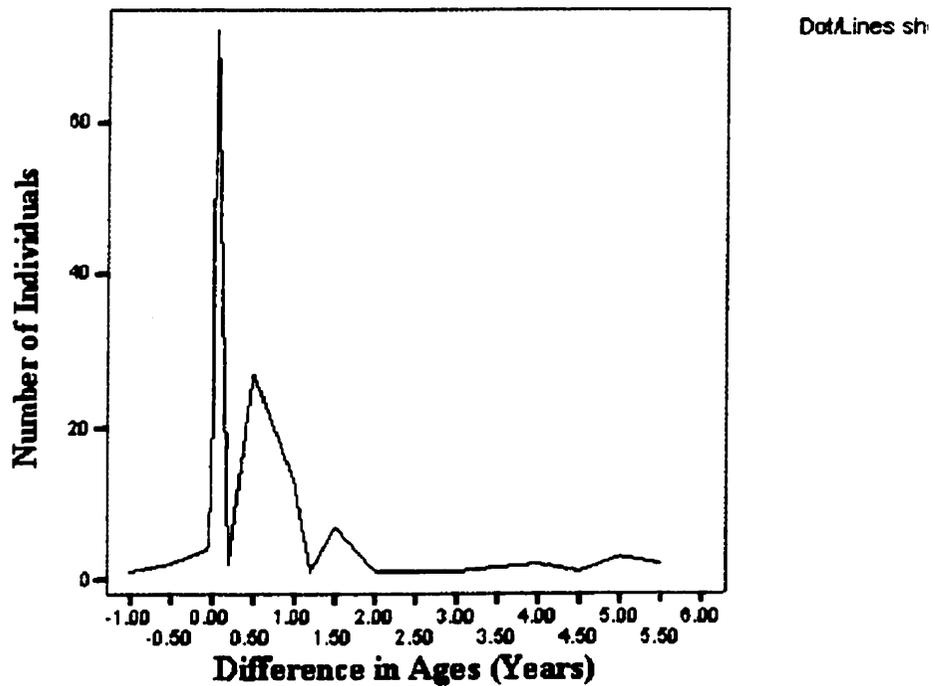
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MEAN DIFFERENCE =	0.282
SD DIFFERENCE =	0.441
T = 7.609	DF = 141
p = 0.000	

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*Table 8: Paired samples T-test comparing the means of ages derived from the Fairty femora using the methods of Maresh (1955) and Merchant and Ubelaker (1977), only on those individuals less than 12 years of age.*

**Fairy Diaphyseal Ages:  
Mean Differences**



*Figure 5: Line graph depicting the mean differences between ages predicted by the Maresh (1955) and Merchant and Ubelaker (1977) methods for the Fairy femora.*

The graph indicates that the majority of femora are exhibiting no difference in age determination by method. Approximately 25 femora exhibit a difference of 0.5 years in age calculation, and less than 10 individuals exhibit a greater difference in age by half year increments. A more direct way of interpreting exactly which ages are exhibiting the most difference is by graphing the differences against the age determinations for each method. Graphs for both the Maresh (Figure 6) and Arikara (Figure 7) standards are presented below, for all ages.

### Fairty Femora: Maresh Ages vs. Difference in Ages

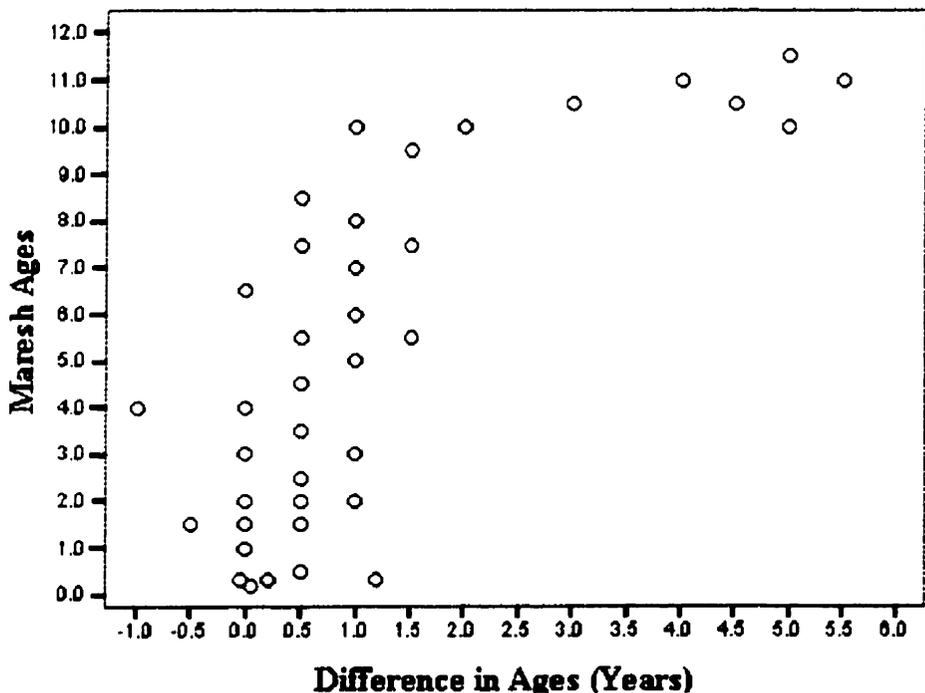


Figure 6: Scatterplot of ages determined by the Maresh (1955) method against the differences in ages between the Maresh and Merchant and Ubelaker (1977) (=Arikara) methods for the Fairty femora.

### Fairty Femora: Arikara Ages vs. Difference in Ages

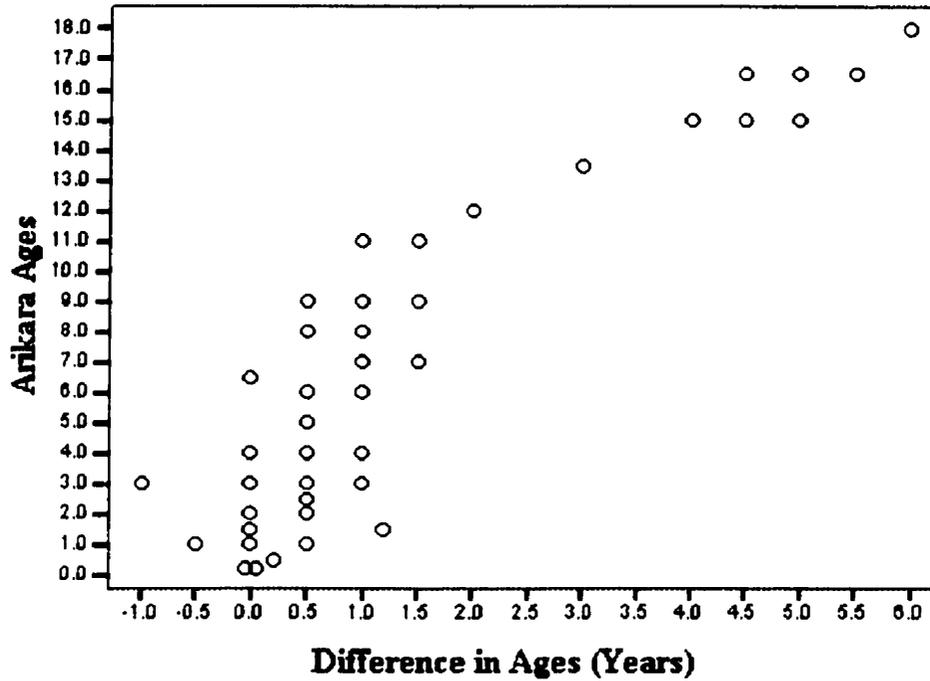


Figure 7: Scatterplot of ages determined by the Merchant and Ubelaker (1977) (= Arikara) method against the differences in ages between the Maresh and Merchant and Ubelaker (1977) (=Arikara) methods for the Fairty femora

The difference in years for both graphs was calculated by subtracting the Arikara ages from the Maresh ages. Subtracting the Maresh ages from the Arikara ages would simply invert the values. It is apparent from both graphs that the greatest difference is seen in individuals older than eight years of age. Up to approximately 5 years of age, the difference tends to be zero to .5 years only, although there are some outliers. The greater differences in the older age categories are due to the failure of the methods at predicting accurate ages, as outlined above.

## ***Palaeodemographic Reconstruction and Inferences about Subadult Growth and Health***

In order to attempt a palaeodemographic reconstruction of a sample and use it to make inferences about the living population from which it was drawn, careful consideration of the methods used to derive the ages and sexes of the sample must be made. This research only addresses age at death, and then, only of juveniles. The many problems with palaeodemographic reconstruction are well known (Bocquet-Appel and Masset 1982, 1985, Jackes 1992, Van Gerven and Armelagos 1983, Wood et. Al. 1992). These are not, however, the focus of this research.

A minimum number of 155 subadults was derived from measurable left femora for this sample. The most subadults from the Fairty sample are calculated by counting the right femora, at 226 individuals. Many of the right femora were however not measurable, therefore the more complete left femora were used for the age determination. Stringent attempts at matching mandibular portions were undertaken, both macroscopically and radiographically. The minimum number of subadults represented by mandibular portions is 220 (including the 50 right hemi-mandible portions). In order to be absolutely certain that no individual was represented twice in the age estimation from the dentition, a subgroup of aged juveniles was extracted from the sample to be used in some tests. This subgroup is based upon the most numerous single tooth, which is the right first premolar. There are 74 distinct individuals represented by mandibles or portions thereof with this tooth present. This provides a sub-sample of 124 individuals when combined with the infant right hemi-mandibles. There are an additional 11 individuals represented by fused infant mandibles with postmortem loss of the teeth, and 20 mandibles with all permanent teeth except the third molars erupted (approximately 12 to 21 years). If these additional 31 mandibles are added to the juvenile MNI (recognizing that some of the 20 older mandibles could derive from adult individuals), then the most restricted number of individuals represented by mandibles or portions thereof is 155. This equals the number of measurable left femora from the sample, but is far below the 226 individuals represented by right femora or portions of right femora. In order to approach equality of numbers between the two samples, one needs to accept that each of

the original 220 mandible portions do represent a single individual only, and add the 11 fused infant mandibles with postmortem tooth loss. The 20 mandibles with permanent teeth but the M3 unerupted can be considered to have derived from individuals older than 16 years, and be omitted from this subadult sample. The total number of individuals represented by mandibles or portions of mandibles is then 231. This exceeds the 226 individuals from the femora by only 5, and suggests that the femora and mandibles are representing an equal number of individuals which have been equally sampled.

All of the above permutations may seem like an exercise in confusion. There is however a point which is illustrated by the seemingly meandering attempt at equalizing the sample sizes. If one is to get as far as justifying the use of ossuary samples for reconstruction of palaeodemography of Southern Ontario prehistoric populations (by accepting the closed, stationary population which only lasted ten years which contributed to the ossuary), and then to utilize these data for making inferences about health, very careful consideration of the methods of determination of age at death, and the subsequent translation of the methods into ages in a chart, or for use in statistical analysis must be done. Examples derived from this and other studies on the Fairty ossuary will be used to illustrate this point.

Anderson (1964) presents a distribution of individuals by age in his report on the Fairty remains. The subadult remains were aged by fusion of parts of the axis vertebrae (93 of 144 were aged in this way). The 144 individuals were represented by temporal bones on which the full length of growth of the tympanic plate had not been reached. To complete the subadult sample, Anderson calculated an adolescent portion by subtracting 144 immature temporals from 217 humeral diaphyses resulting in 73 individuals aged 12 to 17 years. The following graph (Figure 8 ) illustrates the number of individuals in each age group compared to the number of individuals in the same age group from this study, aged by different means.

## Fairty Comparative Ages

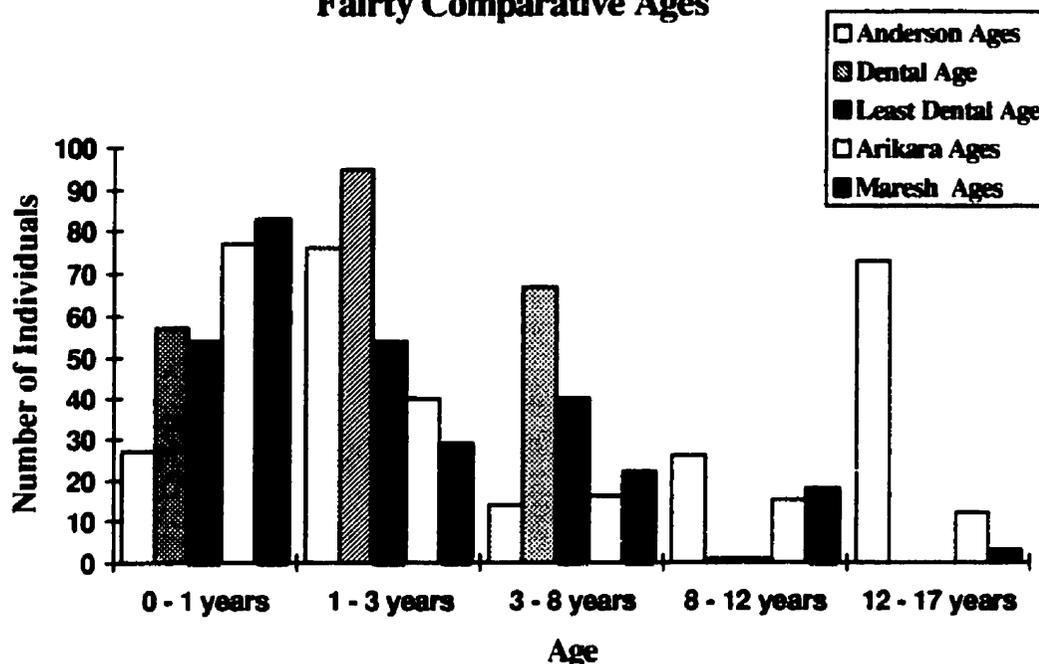


Figure 8: Bar graph of dental ages for the Fairty sample transformed by different methods and by different researchers.

It is readily apparent that the number of individuals in Anderson's (1964) broad age groups are very dissimilar to the numbers generated by various means from this analysis. The lack of newborn remains (0 to 1 year) can only be explained by their having been included in the later category (1 to 3 years), but this does not account for all of them. Anderson aged the subadults by fusion of parts of the axis vertebra (1964:32), but none of the separate parts (4 at birth) of the axis fuse until between 3 and 6 years (Romanes 1981). Anderson presents his vertebral developmental sequence in a later publication (Anderson 1969). In this sequence, he shows an unfused neural arch at birth, a progressive fusion of the arch from lumbar to cervical region at age two, arch fused to body from lumbar to cervical region at age 7, and two stages of fusion for the secondary centres at and after puberty. This developmental sequence would not have been very exact for determining the age at death of separate vertebral elements. The next age indicator by epiphysis for the axis is the center for the dens. This begins to ossify

between 2 and 6 years, but does not complete fusion until 12 years of age (Romanes 1981, Williams and Wilkins 1980). The fusion of the centre for the dens no doubt provided Anderson with his upper age limit for the pre-pubertal group, but it is unknown how he separated the 3 to 8 and 8 to 12 year groups. A final question is raised by Anderson's age determination of the "pre-pubertal" group (0 to 12 years), by the development of the tympanic plate. The most recent research on the development of the tympanic plate clearly shows that it is fully developed by 2.5 years of age (Weaver 1979). No references could be located that suggested that the tympanic plate continued to grow until maturity was reached at 12 years of age. One hundred and forty four subadults up to age 3 years more closely matches the numbers derived from this analysis (e.g. Arikara = 117, Maresh = 112, dental = 152, least dental = 108). It follows that some of the 73 adolescent individuals are most likely younger than 12 to 17 years at death.

When Anderson (1964) published his analysis of the Fairty material, it was lauded as the first scientific analysis of an ossuary. Anderson could only use the standards for age determination which were available at the time. Moorrees et al.(1963a, b and Merchant and Ubelaker (1977) had yet to publish their standards. Melbye (1984) correctly states that Anderson never intended his age distribution pie chart to be "subjected to the rigors of life table calculation" (Melbye 1984:2). Unfortunately, it was. Ubelaker (1974:64) attempted to compare death rates by age of the Fairty sample with two ossuaries from Maryland, but found Anderson's (1964) age intervals and uncertain criteria for determining *adult* age to preclude a close comparison. He did however generally compare the two samples and concluded that his populations showed higher infant, and lower adolescent mortality rates. Melbye (1977) assessed the seeming lack of infants in the sample, and proposed an "infant correction factor". This correction factor was also applied to the Ossossané ossuary (Sullivan and Melbye 1978). Katzenberg and White (1979) present survivorship curves for the Fairty sample (as well as others), for both adjusted (infant correction factor included) and unadjusted data. The irony in the evolution of the infant correction factor (for Fairty, and probably for Ossossané as well - although now we will never know), is that it was not necessary. Infant mortality is high in this sample, as the present study has demonstrated. Accepting Anderson's age distribution as fact, and applying a correction factor to increase the number of infants in

the sample, appears to have brought the number of infant deaths up to a level of reality (or at least the level found in this study). Any analysis which utilizes the mortality curves of Fairty with the adjusted infant ages is probably correct in its conclusions. There is still the problem, however, that Anderson's methodology likely inflated the number of adolescent dead.

Jackes (1986) used the Fairty ages derived from Anderson to address the broader question of mortality of Southern Ontario archaeological populations in general. She used a conservative constant to correct for infant under representation, and manipulated the data from this and other sites to provide mortality curves and measures of mean childhood mortality. The mortality curve generated for Fairty did not compare to any other pre-contact site (low infant mortality and high adolescent mortality). Jackes expends much discussion attempting to explain why this might be so, but does not accept that the age estimates may be inaccurate (1986:38). She concludes by stating that the sample is biased. All samples of dead should be considered to be biased, and attempts at inferring information about the living population from the dead should be considered tenuous at best. This discussion will be dealt with further below. The point here is that if any researcher wishes to make inferences about the health and mortality of prehistoric populations, they must return to the bones and collect the primary, basic data on age and sex themselves.

Inferences about health from the Fairty remains have been published. In two cases, the researchers actually did go directly to the bones and assess certain markers of stress observed on them. Both Larocque, (1991) and Katzenberg (1992) scored periostitis on the tibiae of juveniles and adults in order to address the presumed changes in health pre- and post-agriculture, and pre- and post-contact. Katzenberg (1992) assessed 581 tibiae, both left and right (of a possible 1024, based on Anderson's MNI), and Larocque (1991) looked at 225 right tibiae (of a possible 512). Both researchers looked only at the complete tibiae. From these observations, they published the results of the percent of individuals affected, and used them to further hypothesize about the health

of the *living* populations.<sup>6</sup> The potentially flawed results (due to lack of inclusion of *all* tibiae) are then used to interpret population health on a broad scale both temporally and geographically in Pfeiffer and Fairgrieve (1994). The authors recognize that data from sites varies according to each osteologist's preference, experience and research expectations, and even state that different researchers have come up with nearly opposite conclusions derived from collecting the same data from the same sample. They forge ahead with conclusions based upon this data nonetheless. This is the nature of research after all.

What then can be said when a careful re-analysis of the ages of death of the Fairty subadults is complete? The graph below shows a comparison between predicted ages from the dentition and the long bones of the Fairty juveniles, utilizing the high estimate of individuals from mandible portions (220) (Figure 9 ).

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<sup>6</sup>Laroque (1991) observed nearly twice the cases that Katzenberg (1992) did. Both researchers found a higher rate of periostitis at Fairty than at Kleinburg (although only slight). Laroque states that the Fairty remains more often exhibit healed lesions, and are different from Kleinburg and Ossossané which exhibit more severe lesions. He sees this as an evolution of the skeletal response to more infectious diseases (including epidemics) with contact. Katzenberg's explanation of the higher incidence of periostitis at Fairty as a reflection of the stresses of an early agricultural group (introduction of a poorer diet relying on maize, and a higher population density with settlement) may no longer be tenable in light of the much earlier carbon 14 dates presented here for Fairty. It is unlikely that the people of Fairty were relying that heavily on maize, although some degree of sedentism and maize horticulture was likely.

## Fairty Estimated Ages

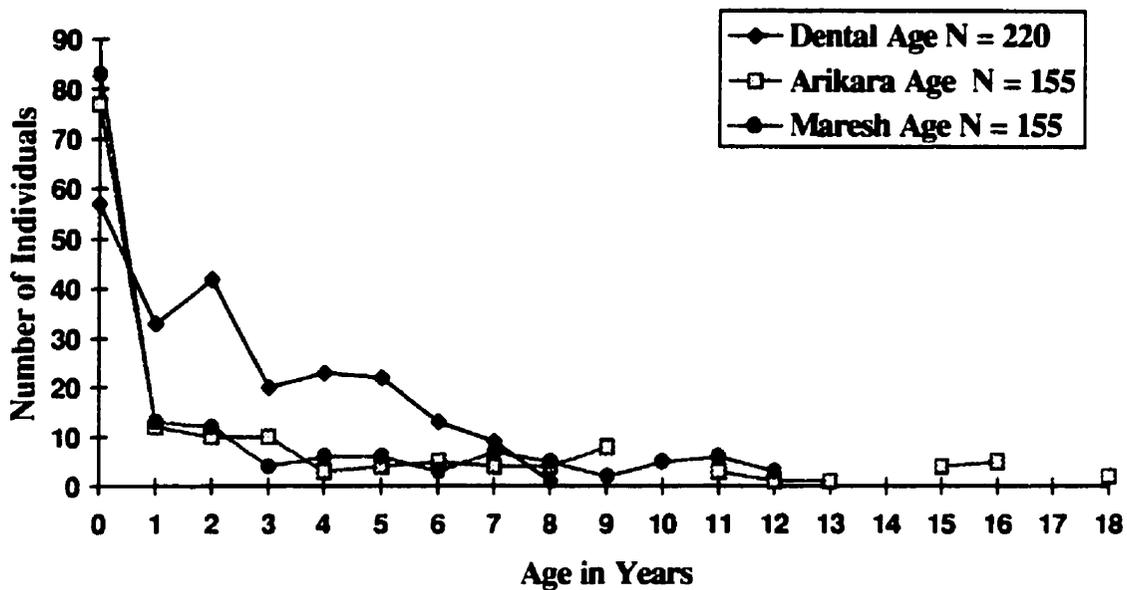


Figure 9: Line graph illustrating the distribution of the dental and femoral ages derived from the Fairty sample.

It is clear that the dental remains consist of less infants (0 to 1 year of age), and more children 1 to 6 years of age. There is an even higher overrepresentation of individuals by teeth in the 1 to 2 year category. Recognizing that these differences may be a byproduct of an inflated number of individuals as represented by mandibular portions, a similar graphic presentation was done, this time utilizing the minimum number of individuals represented by the right first premolar and the unfused hemi-mandibles (124). This is presented in Figure 10 below.

## Fairty Estimated Ages - Least Dental Remains



Figure 10: Line graph illustrating the distribution of the least possible number of dental ages with all femoral ages derived from the Fairty sample

This graph shows that although the numbers are reduced, the result is the same; less infants and more children in the 1 to 6 year categories, as predicted by dental age standards. In order to ensure that sampling was not introducing bias, as only 155 left femora were measurable and therefore ageable, from a total of 226 subadult individuals, another check of these un-measurable diaphyseal portions (both femoral and humeri) was done. They appear to represent a range of sizes, suggesting that they are removed from the database at random. This assumption must be maintained in order to hypothesize any further. Potential methodological problems with the dental calcification ages have been discussed, and do not seem to be a problem here, at least, not one which can be addressed. Another potential source of error is the method for deriving diaphyseal length from shaft end breadths (Hoppa and Gruspier 1996), which was applied here. The method served to increase the number of ageable individuals (by predicting lengths of diaphyses) most heavily in the 0 to 5 year age categories. A comparison of diaphyseal

length with length predicted by the proximal head of the femur for the Fairty sample reveals an adjusted  $r^2$  of .983, and a standard error of the estimate of 13.895. While the correlation is good here, the standard error is somewhat high and could be contributing to the inclusion of an individual from 0 to 1 years in a higher age category. Even if this is true, we still have elevated levels of children aged 1 to 6 years by dental remains. Additionally, the trend does not continue after age 6 years by teeth, although there are individuals represented in these older categories by long bones. Specifically, there are thirty-two individuals older than 6 years by the Arikara (Merchant and Ubelaker 1977) standards, and thirty-three individuals older than six years by the Maresh (1955) standards. At least some of these would have had mandibles which were not included in this study due to the loss of the deciduous dentition (at least twenty were noted with permanent dentition except for the third molars, erupted). The problem with determining acceptable ages for diaphyses over the age of nine years has been outlined above, so there are methodological problems with the transformation of diaphysis into age also. If one chooses to accept that there is a biological difference between the stage of development of the dentition and the length of the diaphysis of the femur and it is not due to methodological problems, as these data seem to suggest, then inferences can be made. As a final comparative check, the ages are presented below as a percentage of the total for each category, as a method of making the results more comparable (Figure 11).

## Fairty Estimated Ages - Percentages



Figure 11: Line graph illustrating the distribution by percentage of the dental and femoral ages derived from the Fairty sample.

Figure 11 showing the percent of individuals in each age group clarifies that the deficit in subadults by diaphyseal length noted above, is not due to unequal sample sizes.

If one accepts that the dental ages most closely reflect the chronological ages, then a portion of the subadults are exhibiting long bone lengths which predict them as being at least one year less than their chronological age, up to the age of seven years. This would account for the increase in infants by diaphyseal age, as they were in reality one to two years of age, or older. This means one of two things. Either this is a biological reality, and the decreased height for age is a trend which should be reflected in the adult mean statures (generally shorter than modern Caucasian samples, or the protohistoric Arikara), or there were some extrinsic factors which were “stunting” the growth of the children in this sample.

The next logical step in this analysis would be to demonstrate statistically, that there was indeed a difference in numbers of individuals by age standard in each cohort. A T-test compares mean values and then gives an overall mean difference. More precision is necessary here. Analyses of variance, either parametric (ANOVA) or non-parametric (Kruskal-Wallis) assume that the samples are independent, which is not true here, therefore they cannot be used. The samples, although related, are not paired either so any tests assuming this cannot be used. A consultant was employed from the Statistics Department at the University of Toronto. A number of attempts at modeling procedures which could identify whether a difference in age by method was greater than any difference introduced by the error of each method were presented. The consultant and the writer worked through each model and found none to be appropriate. The consultant offered that it would take much more effort to find a solution, if indeed one were possible (K. Wong pers com.). The same problem disallows any observations on which diaphyseal method may be more comparable to the dental age method used

The most potentially important cause for the differences in ages of individuals in the Fairty sample lies within the standards used for producing the ages. Saunders and Hoppa (1993) state that methodological bias is generally greater than any real deficit in growth, and will thereby obscure it, or as would be true in this case, produce an artificial difference in ages which appears as a diaphyseal growth deficit. An investigation as to whether the standard deviation around the mean ages calculated for these individuals is greater than the actual difference in age by one year cohort was attempted by graphical comparison.

A sub-sample of fifty individuals was chosen at random from each of the dental and diaphyseal age databases. The diaphyseal age standards utilized were those of Maresh (1955), as they are derived from a similar population (White modern children) as those of Moorrees et al. (1963a, b). The upper and lower limits of the range around the mean age were derived for the femoral diaphyses by consulting the original publication (Maresh 1955), and including all ranges which the length fell into. The upper and lower limits around the means of the dental ages were derived by extracting the lowest mean age and the highest mean age predicted from any tooth within a mandible. All mandibles

in the sub-sample had at least ten teeth contributing to the mean age. Each of the lowest and highest mean ages would have a lower and higher age limit if compared to the box and whisker plots of Moorrees et al. (1963a,b). In most cases, the lowest and highest mean age was contributed by a single tooth only (out of ten or more), and the further widening of the age range would likely be artificial. It is however, noted here. Two graphical presentations of the mean ages with the upper and lower limits of the ages are presented in Figures 12 and 13 below.

### Fairty Dental Age Means and Ranges

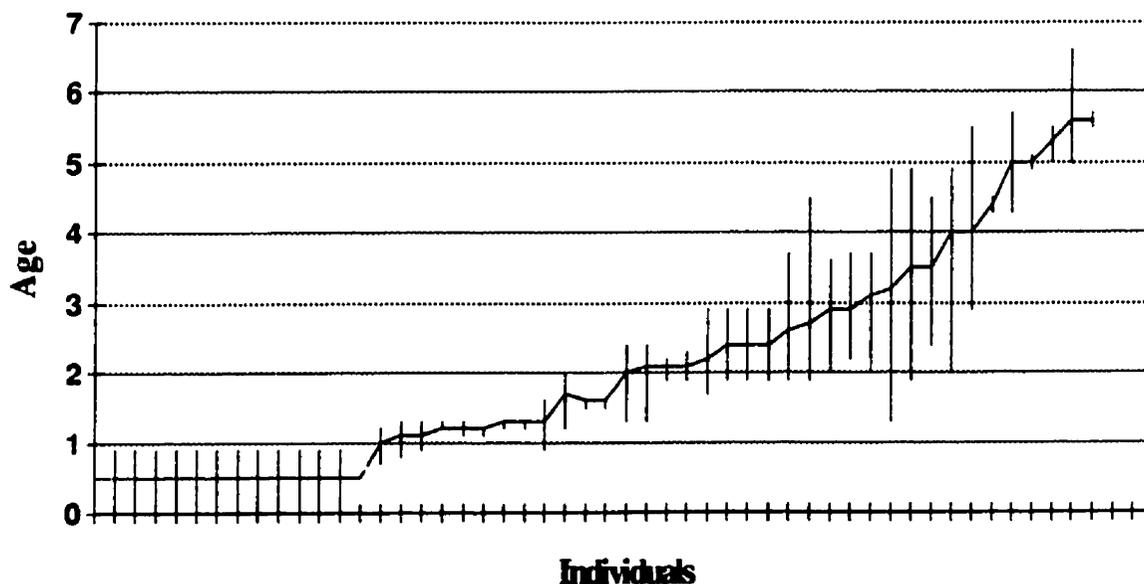


Figure 12: A random sample of 50 dental individuals from the Fairty sample. Mean and ranges are presented.

## Fairty Femoral Age Means and Ranges

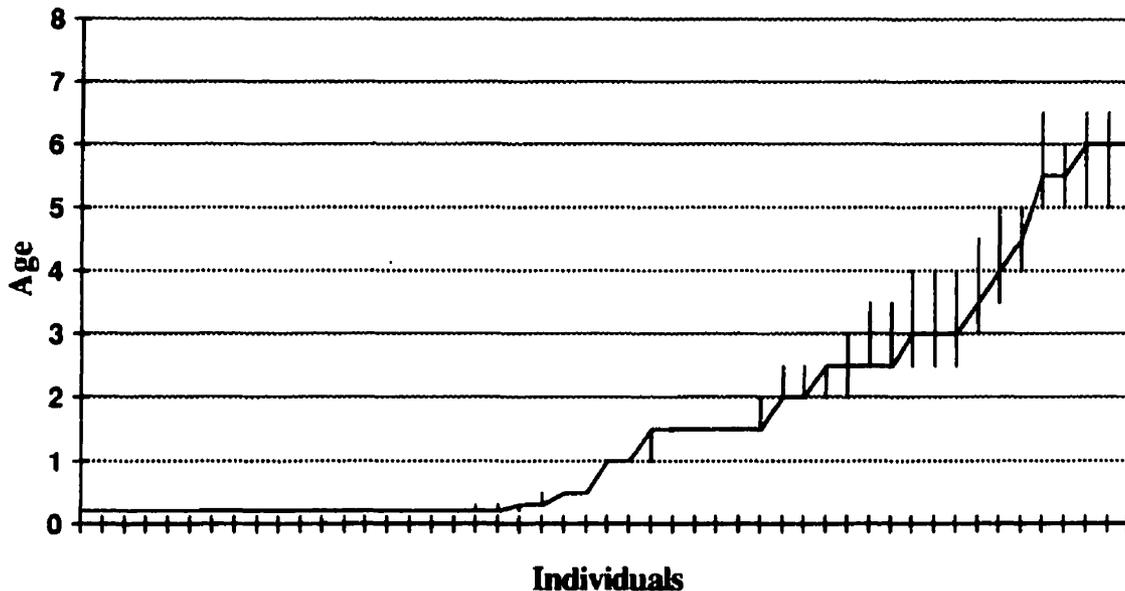


Figure 13: A random sample of 50 femora aged by the Maresh (1955) method from the Fairty sample. Mean and ranges are presented.

There is no overlap in age range from the 0 to 1 year group into the next age group. What this means is that none of those individuals aged 0 to 1 year by diaphyseal length could be aged 2 to 3 years by dental calcification purely by virtue of the standard error of the methodology. Similarly, very few of the individuals aged 1 to 2 years by dental remains could actually be aged less than 1 year (4 of the 13 individuals show a slight possibility of having an actual age less than 1 year). There is more of a possibility of a 2 to 3 year old actually being a 1 to 2 year old aged by dental remains alone, but this does not present a particular problem with the scenario presented here. In fact, more 2 to 3 year olds may actually be 3 to 4 year olds by the dental aging method. The possible bias introduced by the standards for both the teeth and the diaphyses becomes much more apparent after three years. A very important observation can be seen by comparing the two figures; the dental ages generally present more of a range of possible ages than do the diaphyseal ages. It is generally held that dental aging is more accurate, but Figure 12

clearly shows the possibility for an erroneous age, particularly if the number of teeth observed is few, and more so if those few teeth happen to include one or more of the outer limits of the age range. Utilizing one or a few teeth to make an age determination is not adequate.

Through a careful analysis of the Fairty juvenile remains, controlling for environmental, cultural and methodological bias as strictly as possible, it has been demonstrated that the most likely explanation for the observed differences in age between the dental and femoral remains, particularly between the 0 to 1 and 1 to 2 year age cohorts, is a biological one. Statistical “proof” for this cannot be offered at this time. Whether this “stunting” is reflecting normal variation for the prehistoric people of Fairty, or whether it signifies poor health in the infants will require further research of a much more refined nature.

## **The Kleinburg Ossuary**

### ***The Teeth***

As with the Fairty sample, all of the mandibles containing developing dentition (with the exception of the third molar) were radiographed. Many of the Kleinburg mandibles were complete with a relatively complete set of teeth remaining in the jaw. This site had been excavated by an anthropologist (F. J. Melbye), hence the careful guarding against loss of the teeth postmortem, during excavation. The number of mandibles or portions of mandibles radiographed was 148. The absolute minimum number of individuals represented by the mandibles or portions of mandibles is 75, based upon the most numerous single tooth, which is the permanent left canine. In order to maximize the number of ageable individuals from the Kleinburg sample, a careful survey was conducted of the actual mandibles and the radiographs. An exclusive number of aged individuals was derived from all of the complete mandibles, added to the portions of mandibles with mentons and right halves, added to the right halves of mandibles without extant mentons. The total number of subadult individuals to approximately 10 years of

age derived by this method is 134, 131 of which are aged by dental calcification, and utilized for the comparative aspects of this study. A total number of 1451 dental scores were entered into the database for statistical manipulation.

All teeth were scored using the Moorrees et al. (1963a, b) dental calcification standards, except for those with the apex complete. Incisors were included at this stage, in order to determine if the ages predicted by them were as different from the ages estimated from the other extant teeth, as they were with the Fairty sample. A Pairwise Spearman Correlation Coefficient was performed between each tooth in every mandible, between left and right teeth and between each tooth and the average for male, female, and sexes combined. Complete results for all teeth using both a Spearman and Pearson Coefficient (as outlined above) were generated. Only the results of the correlation for the mean ages by sex and mean age, sexes combined are presented in Table 9 below.

Tooth		Mean Age Female	Mean Age Male	Mean Age Sexes Combined
Left first deciduous molar	$r_s$	.953 ***	.940 ***	.958 ***
	N	(21)	(23)	(23)
Right first deciduous molar	$r_s$	.948 ***	.942 ***	.952 ***
	N	(30)	(31)	(31)
Left second deciduous molar	$r_s$	.843 ***	.986 ***	.966 ***
	N	(30)	(29)	(29)
Right second deciduous molar	$r_s$	.957 ***	.964 ***	.962 ***
	N	(37)	(38)	(38)
Left first permanent incisor	$r_s$	.807 ***	-0.000 <sup>ns</sup>	.807 ***
	N	(9)	(3)	(9)
Right first permanent incisor	$r_s$	.837 *	-0.000 <sup>ns</sup>	.837 *
	N	(7)	(3)	(7)
Left second permanent incisor	$r_s$	.436 <sup>ns</sup>	.171 <sup>ns</sup>	.436 <sup>ns</sup>
	N	(8)	(8)	(8)
Right second permanent incisor	$r_s$	.949 <sup>ns</sup>	.866 <sup>ns</sup>	.949 <sup>ns</sup>
	N	(4)	(3)	(4)
Left permanent canine	$r_s$	.918 ***	.920 ***	.921 ***
	N	(75)	(75)	(75)
Right permanent canine	$r_s$	.853 ***	.899 ***	.895 ***
	N	(72)	(72)	(72)
Left permanent first premolar	$r_s$	.935 ***	.945 ***	.948 ***
	N	(67)	(67)	(67)
Right permanent first premolar	$r_s$	.929 ***	.943 ***	.950 ***
	N	(70)	(71)	(71)
Left permanent second premolar	$r_s$	.956 ***	.957 ***	.957 ***
	N	(54)	(54)	(54)
Right permanent second premolar	$r_s$	.937 ***	.933 ***	.936 ***
	N	(60)	(60)	(60)
Left permanent first molar	$r_s$	.940 ***	.947 ***	.945 ***
	N	(59)	(60)	(60)
Right permanent first molar	$r_s$	.940 ***	.949 ***	.947 ***
	N	(61)	(60)	(61)
Left permanent second molar	$r_s$	.958 ***	.962 ***	.957 ***
	N	(31)	(31)	(31)
Right permanent second molar	$r_s$	.917 ***	.913 ***	.914 ***
	N	(34)	(34)	(34)

ns = not significant

\*  $P \leq 0.05$

\*\*  $P \leq 0.01$

\*\*\*  $P \leq 0.001$

Table 9: Spearman Correlation Coefficient results for the Kleinburg dental sample; each tooth by mean for sex, and sexes combined.

The correlation between separate tooth ages and the mean age by sex and combined sexes is generally highly significant. As with the Fairty results, this is to be

expected, as each tooth is contributing to the mean age at death. Correlation between all teeth within any given mandible was similarly significant at  $p \leq 0.001$ . The incisors (with the exception of the left first permanent incisor present non-significant correlation or significance at  $p \leq 0.05$ ). The sample sizes for the females are very small, making it difficult to assess whether the results are valid or not. A lack of data for the male standards precludes any assessment of correlation. For these reasons, it was decided to follow the same methodology as that of the Fairty sample, and exclude the incisors from the calculation of mean age for further analysis.

All of the ages derived from separate teeth from any mandible or portion thereof were averaged by sex. The mean age by sex was then averaged to provide dental calcification ages for the “ageable” sample. The results are graphically depicted in Figure 14 below.

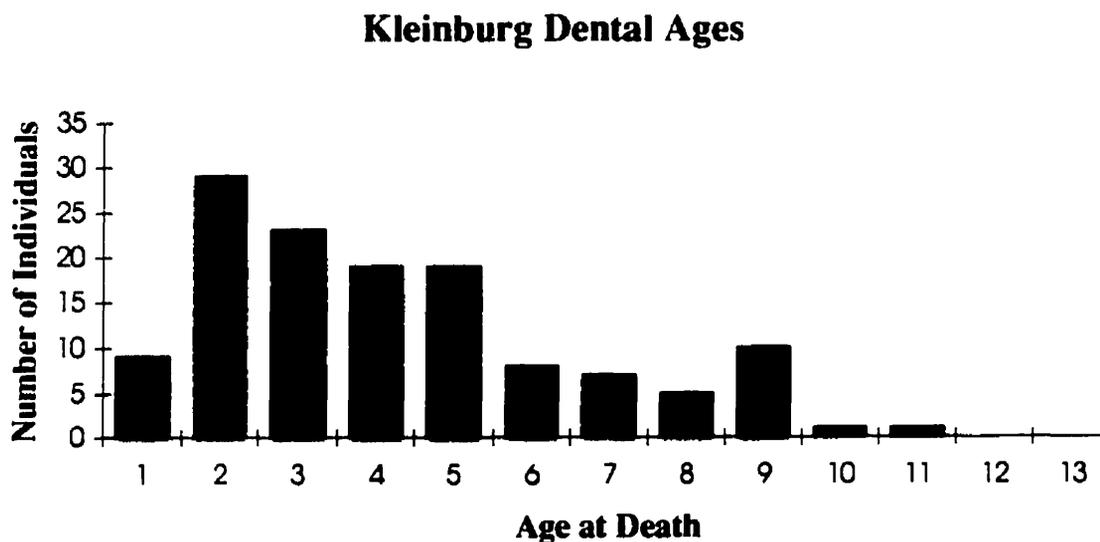


Figure 14: Histogram of mean dental ages for the Kleinburg ossuary sample.

### ***The Long Bone Diaphyses***

The Kleinburg skeletal remains had been excavated, stored and mended under the curation of a physical anthropologist (F. J. Melbye). This collection has been used by many researchers over the years. It was assumed that the labeled boxes contained all bones of that description, and that fragment boxes would not add to total bones. Very few boxes of unanalyzed fragments, in fact, exist. Those that do contain very analyzable fragments!

The diaphyses of the femora, humeri and tibiae were measured. Both complete diaphyseal lengths were taken, and selected measurements of the proximal and distal ends. These measurements were the same as those taken on the Fairty sample, and were also later used to test the relationship of diaphyseal length to end breadths in selected bones (see Hoppa and Gruspier 1996, Appendix 1).

The Pearson Correlation Coefficient was applied to the Kleinburg sample in order to determine if the end breadths were correlated with diaphyseal length and could therefore be used to derive diaphyseal length. A number of bones were tested in order to determine which had the best correlation between end breadth and diaphyseal length. For the Kleinburg sample, a number of new measurements were added. The radius and the tibia with proximal and distal end measurements were tested, and a measurement of the length of the femoral neck was contrived. The definitions of these measurements can be found in Hoppa and Gruspier (1996): The results are presented in Table 10 below.

	Diaphyseal Length	Proximal Breadth		Neck Length		Distal Breadth	
	N	N	r	N	r	N	r
Left Humerus	64	57	.9438			58	.9409
Right Humerus	62	57	.9570			54	.9710
Right and Left Humeri	126	114	.9503			112	.9557
Right Radius	43	40	.9741			30	.9596
Left Femur	46	39	.9787	38	.9896	69	.9813
Right Femur	43	33	.9791	37	.9886	32	.9199
Right and Left Femora	89	72	.9787	75	.9891	70	.9379
Left Tibia	50	33	.9777			35	.9752
Right Tibia	56	34	.9754			38	.9776
Right and Left Tibiae	106	67	.9739			73	.9766

*Table 10: : Results of Pearson Correlation Coefficients for the Kleinburg humeri femora and tibiae. Diaphyseal length versus proximal and distal end breadths.*

The results indicate that there is a very significant degree of correlation between distal and proximal end breadth and diaphyseal length for all of the bones measured. All of the results are significant at the  $p < 0.0001$  level. The femora showed the highest correlation, followed by the tibiae, radii and finally the humeri.

In order to derive a prediction equation for estimating diaphyseal length from an end breadth, a linear regression model had to be applied to the data from this sample, as was done for the Fairty sample. The results of the correlation suggested that they were less significant than the correlation coefficients from the Fairty sample, so the measurements from both sites were combined to produce a better model. The assumption was made that the Fairty and Kleinburg individuals derived from the same broad biological base, and that the higher correlation coefficients for Fairty were likely a result of the inclusion of the many peri-natal diaphyses which are largely absent in the Kleinburg sample. It was suspected that the youngest individuals in the sample would fit

more tightly into the 0 to 1 year age range, and that variation in membership within an age range would increase as age progressed. This is a biological fact, as has been shown by other skeletal changes which are said to predict age by a continuum of metamorphic change (e.g. Gruspier and Mullen 1991). In order to ensure as far as possible that these two samples could be combined, Hoppa compared the error distributions of the residuals from both samples and found that they were comparable (Hoppa and Gruspier 1996: 351).

The maximum number of individuals was counted on the right humeri, of which 63 were complete, 50 were represented by measurable proximal ends, and 25 represented by non-measurable proximal ends. This results in an MNI of 138 subadults, 113 of which could be measured and used for age determination.

A linear model was applied to the combined data from Kleinburg and Fairty for both left and right humeri, in order to derive a prediction equation for diaphyseal length from the breadth of the proximal end of the humerus. The results are presented in Table 11 below.

<b>Dependent Variable:</b>	LENGTH
<b>Number:</b>	272
<b>Squared Multiple R (R<sup>2</sup>):</b>	0.95948
<b>Standard Error of the Estimate in mm. (s<sub>e</sub>):</b>	12.17259
<b>F-Ratio</b>	6416.56373
<b>P (of F)</b>	<0.0001
<b>Constant</b>	-19.624508
<b>Coefficient (β<sub>1</sub>)</b>	8.113157

*Table 11: Results of a Linear Regression analysis comparing the Kleinburg and Fairty humeral lengths to the proximal end widths.*

The equation derived from the linear regression model [-19.624508 + 8.113157 (proximal breadth)] was applied to the 50 right proximal humeral end breadths and

estimated diaphyseal lengths were obtained. As stated above, these were combined with the 63 complete diaphyseal measurements for a total of 113 aged individuals. The number of “ageable” individuals was increased by nearly 50% by the addition of these transformed proximal end breadths.

The diaphyseal lengths from the right humeri were then transformed into ages utilizing the standards of both Merchant and Ubelaker (1977), and Maresh (1955). Mean ages were derived from either calculating the mean from those ages presented as a range (Merchant and Ubelaker 1977), or the length was matched to the closest 50th percentile value (Maresh 1955). Age estimations of the Kleinburg humeri for both sets of standards are presented in Figure 15 below.

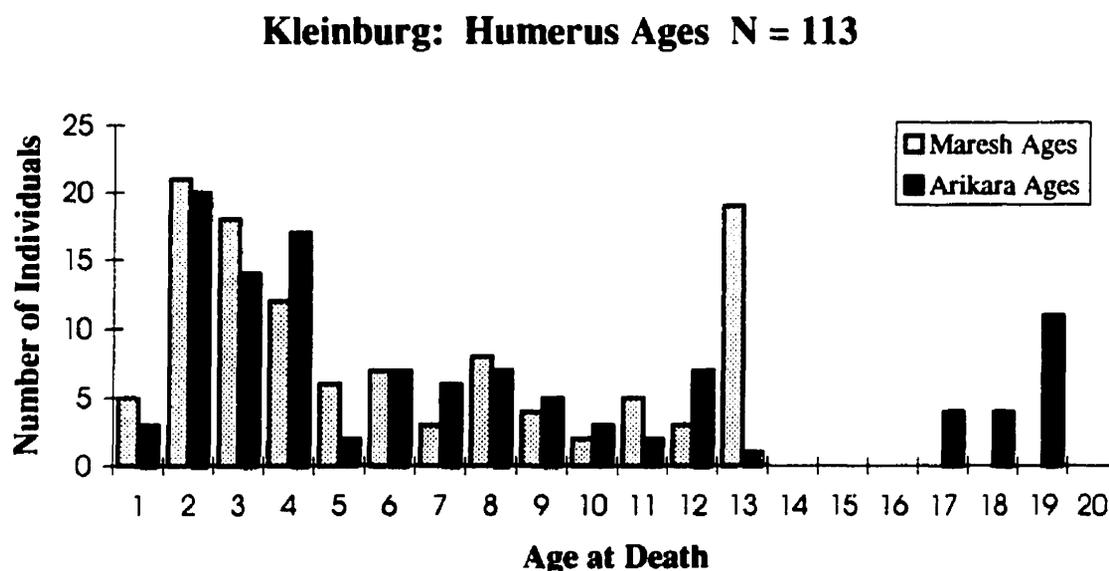


Figure 15: Bar graph of age determinations of the Kleinburg juvenile humeri by the methods of Maresh (1955), and Merchant and Ubelaker (1977) = Arikara.

The Kleinburg sample did not suffer from missing data standards in the youngest age categories as the Fairty sample did. All measurements of the humerus are above the lowest measurement in the range for the Arikara standards (63.5 mm), and the Maresh standards (63 mm). For both sets of standards, a problem arises at approximately 12 years of age. Merchant and Ubelaker (1977) provide a measurement for only one

individual above that age, and Maresh (1955) begins to provide diaphyseal length with epiphyses at that age (this is evident in the “bunching up” of individuals aged by the method of Maresh 1955 at age 13 in Figure 15 above). This is the same methodological problem which was encountered with the femora in the Fairty sample. As with the Fairty sample, few individuals fell into these age categories (approximately 20 here), but with the smaller sample size from Kleinburg, the loss of this data could cause potential problems in attempts at inferring health from the sample.

A paired samples T-test was done on the age estimations calculated from the Maresh (1955) and Merchant and Ubelaker (1977) results in order to determine if the methods were comparable at predicting age for this Huron sample. The results are given in Table 12 below.

**Paired Samples T-Test on Maresh (1955) Estimated Ages vs.  
Merchant and Ubelaker (1977) Estimated Ages  
With 113 Cases**

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MEAN DIFFERENCE =	-1.215
SD DIFFERENCE =	2.164
T = -5.966	DF = 112
PROB = 0.000	

---

*Table 12: Paired samples T-test comparing the means of ages derived from the Kleinburg humeri using the methods of Maresh (1955) and Merchant and Ubelaker (1977).*

The result of the T-test are highly significant, suggesting that the methods are predicting significantly different ages at death from the diaphyseal lengths. In order to investigate if the sample of Maresh ages artificially aged at 12 years was causing this non-comparability, a sub-sample of individuals less than 12 years was chosen. The results were still significant at beyond .0001. The same test was run on a sub-sample of individuals less than 11 years. The results continued to be significantly different beyond

0.0001, although the actual mean difference in years does decrease. Clearly, the artificial “bunching up” of ages from the Maresh (1955) method is not all that is causing these two methods to predict non-comparable ages at death from the same diaphyseal lengths.

### ***Palaeodemographic Reconstruction and Inferences about Subadult Growth and Health.***

The ages at death of the subadults from Kleinburg do not conform to acceptable parameters for populations in the past, and cannot therefore be used to reconstruct the living demography of the population from which they were derived. For whatever reason, the number of neonates is far below what would be expected for a pre-antibiotic population. This sample clearly represents only part of the population from which it was derived. If the neonates are not present in the sample, then one may well assume that it is biased for or against other ages and sexes as well. In addition, it is documented that the ossuary was opened in the last century, and that some remains were removed (see Chapter 3). One prior attempt at reconstructing the mortality rates for Kleinburg was based upon preliminary age data (Pfeiffer 1974), and included an adjustment for under-representation of infants. Jackes (1986) used these preliminary data for cross-sample comparisons. She did state that the result of her manipulations indicating a population with low childhood mortality rates, may have only been a reflection of the lack of neonatal remains in the sample (Jackes 1986).

Sullivan (1988) utilized the mandibular remains from the Kleinburg ossuary in his attempt to address the theory of pre- and post-contact mortality rates amongst the Huron. The usefulness of his research, for the purpose of this study, is that it provides a check on interobserver error (as Saunders and Melbye 1990 do also - see below). Sullivan aged a sample of the Kleinburg mandibles by radiographing them and utilizing the Moorrees, Fanning and Hunt (1963 a, b) standards to derive an age at death for each. Sullivan included his age interpretations in an appendix in his thesis (Sullivan 1988, Appendix A). The following graph depicts the results of Sullivan’s and this study (Figure 16).

### Kleinburg: Comparative Dental Ages (Percent)

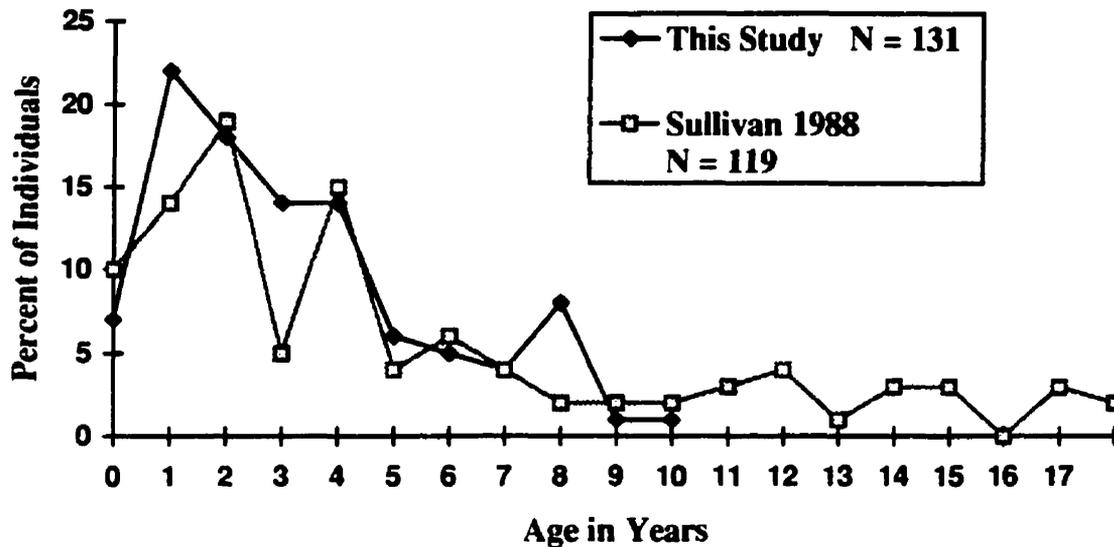


Figure 16: Line graph comparing the distributions of the dental ages for Kleinburg from this study and Sullivan (1988).

It would appear that the ages derived by Sullivan (1988), and those derived from this study are not comparable at the 1 and 3 year marks, where this study shows more individuals. This study has an additional 12 individuals, but this alone could not account for the difference in incidence by cohort. A more precise comparisons was undertaken. Sullivan (1988) and this research were found to have only 81 actual cases in common (deduced from the numerical list of specimens in his Appendix A). Of these 81 mandibles, a similar age was derived in only 44 cases (54%). In almost all of the discrepant cases, the estimates only disagreed by one year. It is not clear how many of the extant teeth within a mandible Sullivan scored. It is clear that he included ages derived from the incisors and third molars (1988:50). A potentially different number of teeth contributing to the age in any one case (less teeth), combined with the biasing effects of inclusion of the ages estimated from the incisors and third molars most likely accounts for these different age estimates. Another possible contributor to the differences could be the way in which the teeth are scored by separate observers. The difference between crown three-quarters and crown one-half for the single rooted teeth appears to be

highly subjective. Any further studies of the inter-observer error in the interpretation of the calcification stages of the teeth would have to be done with another observer. In order to test if these observed differences were statistically significant, an F-Test was applied to the numbers of individuals in each cohort. The F-Test assumes a normal distribution (which must be implied from utilizing the Central Limit Theorem here), and the null hypothesis states that both sample have been drawn from the same population. The result of the test was  $F = 5.820$  ( $DF = 7,3=10$ ). The p value for this result is 0.088 suggesting that the samples have both been drawn from the same parent population. The less robust non-parametric chi-square test was applied to each age cohort to test for association. All of the ages cohorts showed an association between the ages of Sullivan and this study with the exception of the 3 to 4 and 4 to 5 year cohorts ( $\chi^2 = 6.76$ , which is greater than 3.84146,  $DF = 1$ ). This suggests that there is some degree of difference between the ages in those cohorts. Overall, the statistical tests suggest that the ages derived from a similar set of mandibles from this collection by two different observers are largely comparable. Inter-observer error is therefore minimal utilizing the calcification standards of Moorrees et al. (1963a, b).

Given the lack of infants in the sample, inferences about health and growth may however, still be possible. The result of Jackes (1986) study suggests that the Kleinburg population enjoyed low childhood mortality rates. . This is usually an indication of good health for subadults. Sullivan (1988) concludes that the Kleinburg remains derived from a stable, stationary population, not experiencing epidemic disease of any type. Two other studies address this question. Patterson (1984) found that the overall rate of enamel hypoplasia was quite low in the Kleinburg sample (10.6%), and that none was seen on the deciduous dentition. Those hypoplastic defects which were seen occurred at a height on the tooth corresponding to  $3.15 \pm 0.65$  years. He suggests that the defects correspond to weaning age stress (Patterson 1984:261). These results are in concordance with the suggestion by Jackes (1986), that the Kleinburg children were relatively healthy.

Saunders and Melbye (1990) approached the question of subadult health in the Kleinburg sample in a more direct manner. Prior to a discussion of their results, an examination of their age determination results and comparison with this study is

necessary. Saunders and Melbye aged the mandibles or fragments thereof using radiographs and the Moorrees et al. (1963a,b) method. A graph showing their determinations of age at death, and the determinations of age at death derived from this study (using the same method, and presumably the same sample) is presented below (Figure 17).

### Kleinburg: Comparative Dental Ages (Percent)

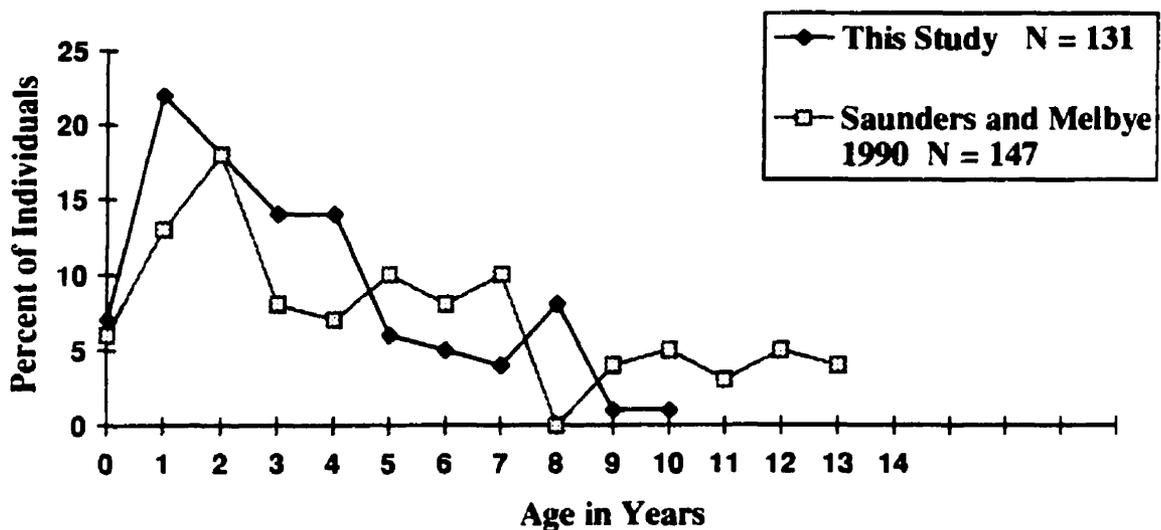


Figure 17: Line graph comparing the distributions of the dental ages for Kleinburg from this study and Saunders and Melbye (1990).

Apart from the birth category, the age distributions do not appear to be at all similar. The sample sizes are similar (a difference of 16 only). The age distribution of the Saunders and Melbye (1990) sample more closely matches that of Sullivan (1988). Other discrepancies of note are, this study included no mandibles aged greater than 10 years, while the Saunders and Melbye (1990) study included individuals aged to 13 years. The peak observed at age 8 years in this study matches that observed at the age of 7 years in the Saunders and Melbye (1990) study. Also, both samples do exhibit a peak of individuals at ages 1 to 2 and a drop in individuals at age 3.

A note should be made here about the sample size and methodology of Saunders and Melbye (1990). Dr. S. Saunders kindly loaned the radiographs from the Saunders and Melbye (1990) study to this author for the present study. For various reasons (some mandibles not radiographed, some x-rays not readable, and an inability to match up all of the x-rays with the extant mandibles), they were not utilized for this study. A total number of 120 mandibles or left or right fragments were counted on those radiographs, not 147 as is stated in Saunders and Melbye (1990). This does not preclude that other radiographs could have been taken. Saunders and Melbye utilized only right mandible portions for their age determinations. They used a minimum of three teeth from each portion. Using only half of the dental arcade may account for some of the differences in final mean age determination. The distribution of the mean ages was accomplished in the same manner as for this study. The observed differences are clearly either due to less teeth being utilized for an age determination (in the case of Saunders and Melbye), or the difference in interpretation of a specific calcification stage of each tooth (both studies). The latter explanation is more likely, as well as more disturbing. If experienced investigators can differ so significantly in interpretation and interpolation of ages from these standards, the potential for methodological bias is greatly increased. Statistical tests for significant differences between the two groups of age determinations were attempted. It should be noted that the data of Saunders and Melbye are presented proportionally and the frequencies are not given. Tests therefore could only compare the percent of individuals in each age cohort, as opposed to the true number. The results of an F-test were 1.607 (DF = 8,2 = 10). The probability is 0.439, suggesting that there is no significant difference in the variances of the two samples, and that they were likely drawn from the same population. No further tests were performed due to the highly significant p value. What appears in the graph to be large differences are in fact not so. This is a strong indicator that interobserver error can be insignificant with this method, even though the latter sample is less complete than the earlier one.

Saunders and Melbye (1990) also determined age at death by diaphyseal measurements of the radii and femora, transformed by the standards of Merchant and Ubelaker (1977). Their sample sizes were 78 and 55 respectively. These samples are too small to be useful for age comparisons with the humeri utilized in this study.

Although a number of individuals represented by non-measurable humeri (25) are not present in this sample, a comparison between the ages at death derived from the mandibles (N = 131) and the humeri (N = 113) was attempted. The results are presented graphically below by both number and percent (Figure 18 and Figure 19).

### Kleinburg Estimated Ages

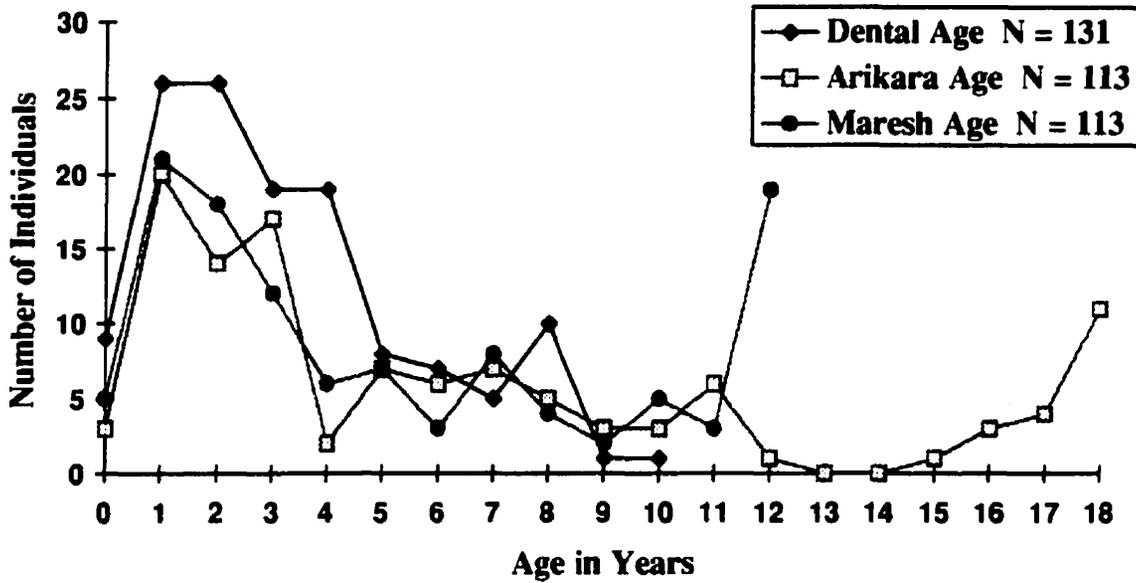


Figure 18: Line graph illustrating the distribution of the dental and femoral ages derived from the Kleinburg sample

### Kleinburg Estimated Ages - Percent

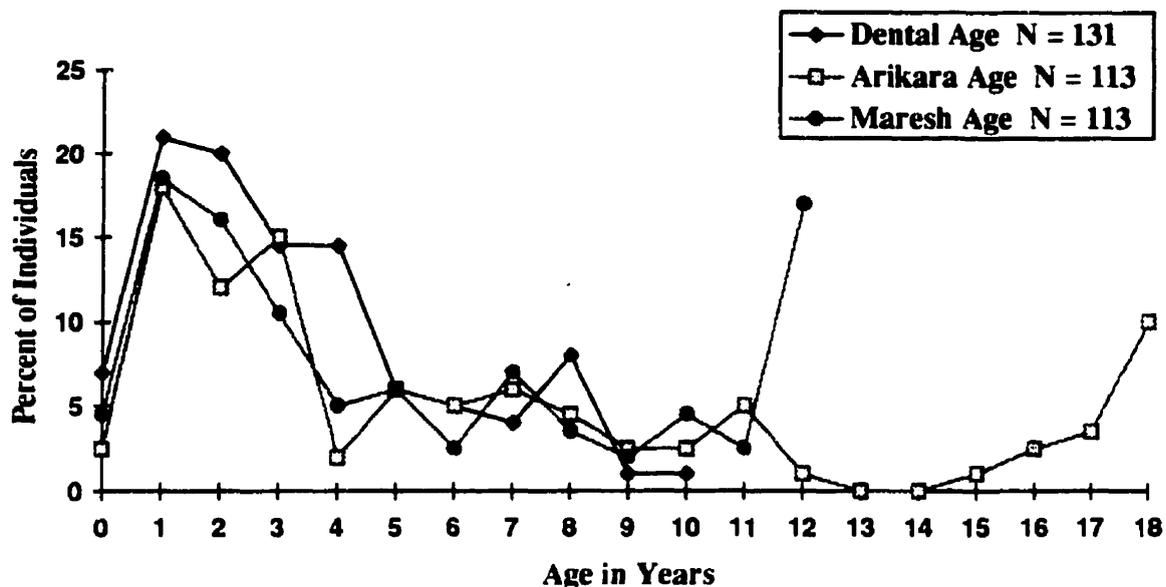


Figure 19: Line graph illustrating the distribution of the dental and femoral ages derived from the Kleinburg sample by percentage.

The presentation of the age results as a percentage of the total number of individuals (Figure 19) appears very similar to the graph depicting the numbers (Figure 18). This is largely due to the fact that the sample sizes approach 100. A slight increase of dentally aged individuals over diaphyseal aged individuals is noted at the 1 and 2 year marks, while there is a substantial increase at the 4 year mark. There is no increase of infants by diaphyseal age. It does appear that something happened to a number of 8 year olds, as there is an increase in frequency by dental age, with a concomitant increase in individuals by diaphyseal age in the 7 year category. This suggests that some “small for age 8 year olds” contributed to the sample. It is tempting to suggest that the same growth deficit hypothesized for the Fairy toddlers is seen here (in particular at the 4 year mark). However, the additional Fairy toddler dental remains were represented by diaphyses of infants, making it more likely that a true biological growth deficit was being illustrated. Here, we do not see a disproportionate amount of infant diaphyses as compared to toddler

dental remains. It is not likely that this sample, analyzed in this way, is telling us anything about subadult health in the population.

Figure 19 does suggest that the humeri and dental remains are representing the same individuals, because the distributions are very similar in shape. The absolute numbers of individuals are similar, there were 25 non-measurable humeri, and a difference of 16 aged mandibles between the earlier study of Saunders and Melbye (1990), and this one. The excluded humeri represent all age categories, but it is unknown what age the missing mandibles are. Assuming that the aged mandibles and humeri are representing the same individuals allows statistical testing which could not be accomplished for Fairty.

A paired samples T-test comparing the means of each age method was done. The assumptions of a normal distribution is not necessary if a large sample size is used. The assumption of an association between each mean had to be made (basically, that any humeri at a given age derived from a mandible of a similar age or, they represent a single individual). The results are given in Table 13 below.

**Paired Samples T-Test Comparing Dental Age with Merchant and Ubelaker (1977) and Maresh (1955)**

	<b>Merchant and Ubelaker</b>	<b>Maresh</b>
<b>Mean Difference</b>	2.929	-1.714
<b>SD Difference</b>	6.085	4.488
<b>T</b>	<b>5.116</b>	<b>-4.060</b>
<b>Degrees of Freedom</b>	112	112
<b>Probability</b>	0.000	0.000

*Table 13: T-test comparing the paired means of the Kleinburg humeri and mandibular elements.*

The results of the T-test clearly show that the ages derived from the diaphyseal data of the Arikara (Merchant and Ubelaker 1977) are significantly different from those derived by dental calcification (Moorrees et al. 1963a,b). The results for the Maresh (1955) ages and dental ages are also significantly different. This suggests that the two samples are not at all comparable in age distribution. The Merchant and Ubelaker method is overaging humeri by a mean of almost three years in comparison to the dental age, while the Maresh standards are producing ages almost 2 years younger than the dental ages. The standard deviation in years is very large. The problem most likely lies in the fact that the dental sample is truncated by the sampling methodology at the 10 year point. There is also the possibility that the artificial “bunching up” of diaphyseal ages using the Maresh method, at the twelve year mark may contribute to the problem. In order to test these hypotheses three more T-test were performed, selecting sub-samples of individuals aged by diaphyseal length. The results are presented in Table 14 below.

**Paired Samples T-Tests Comparing Dental Age with Merchant and Ubelaker  
(1977) and Maresh (1955)**

	Mean Difference	SD Difference	T	DF	P
Merchant and Ubelaker Less than 13 years (N = 94)	-0.800	3.859	<b>-2.011</b>	93	<b>0.047</b>
Merchant and Ubelaker Less than 12 years (N = 93)	-0.692	3.733	<b>-1.787</b>	92	<b>0.077</b>
Merchant and Ubelaker Less than 11 years (N = 86)	-0.147	3.233	<b>-0.422</b>	85	<b>0.674</b>
Maresh Less than 13 years (N = 113)	-1.714	4.488	<b>-4.060</b>	112	<b>0.000</b>
Maresh Less than 12 years (N = 94)	-0.526	3.671	<b>-1.391</b>	93	<b>0.168</b>
Maresh Less than 11 years (N = 91)	-0.272	3.410	<b>-0.762</b>	90	<b>0.448</b>

*Table 14: Paired samples T-tests comparing the Kleinburg dental and humeral ages for subsamples selected by decreasing age.*

The results of progressive selected sample T-tests between dental ages and diaphyseal ages show that both previous hypotheses are correct. The T-test between the Merchant and Ubelaker (1977) diaphyseal ages and the dental ages is not significantly different beginning at the less than 11 year mark. This suggests that it is only the sample bias (no dentition over the age of ten years to compare with the diaphyseal ages) which is causing the samples to appear significantly different. The T-test results for the Maresh (1955) and dental ages suggest that the samples are similar after the less than 12 year age

cutoff. They become even more similar (less significantly different) with the less than 11 years of age sub-sample. Clearly the inability of the Maresh method to age diaphyses beyond the age of twelve years, and the “bunching up” of the older individuals at twelve years is biasing the results. The mean difference in age when only those individuals with dental remains are taken into account (less than 11 years) is merely 0.147 years for the Arikara method, and 0.272 years for the Maresh method. The standard deviations are rather high though, in both cases over three years. The slightly lower mean difference between the dental ages and the Merchant and Ubelaker standards suggests that this method is more accurate for aging individuals in this sample. The mean difference in years between the dental ages and the diaphyseal ages is less than the standard error which is introduced by the methods, the dental ages in particular (usually  $\pm 6$  months), so a true growth deficit could not be shown for this sample. However, if the difference between dental and diaphyseal ages only amounts to a few months, then it really is not a growth deficit at all, but simply normal variation in the timing of growth in children.

The results of the Saunders and Melbye (1990) analysis indicate that the percent cortical area, as well as the absolute values for total area, cortical area and medullary area for individuals aged 1 to 4 years, is significantly lower than the rest of the Kleinburg sample. This they say is consistent with weaning age stress, but does not indicate severe nutritional stress, as reduced bone density is also noted in the adults from this ossuary (Pfeiffer and King 1983). Of note is the fact that they also observed a lower percent cortical area for the seven year old cohort as aged by radii. This demonstrated deficit in growth by apposition does not translate into a deficit of longitudinal growth. This may be due to the physiological response to nutritional stress beginning with the first bone which was formed by endochondral ossification. During periods of stress, osteoclastic activity usually exceeds that of osteoblastic activity in bone. The cortical osteopenia may be indicating early signs of stress, or mild stress, before the osteoblasts responsible for longitudinal bone growth were affected, and stopped longitudinal bone growth.

There is no demonstrable longitudinal growth deficit in the Kleinburg juveniles, and the observed cortical bone reduction does not indicate severe nutritional stress according to Pfeiffer and King (1983). This may suggest that the Kleinburg juveniles

enjoyed quite good health. This corresponds with the findings of Sullivan (1988) who suggested that the Kleinburg people had a life expectancy at birth of nearly 40 years, very similar to that of Fairty, and much longer than that of Ossossané. Jackes (1986) also states that the palaeodemographic reconstruction of the Kleinburg ossuary suggests a low mortality and therefore relatively long-lived population. Somewhat in opposition to this, are the rates of growth arrest lines and cribra orbitalia on the juveniles of the Kleinburg sample. Larocque (1991) notes a frequency of 70% affected juveniles for growth arrest lines, and 34% prevalence for cribra orbitalia in juveniles. It is not the intention here to begin a discursive debate on the meaning of these “nutritionally related” pathological changes, they can be interpreted both as evidence of excessive nutritional deficit, and as a healthy response to some type of nutritional deficit or disease. They do not necessarily imply that the juveniles from Kleinburg were generally ill and malnourished, and if interpreted in this way, are not at odds with the palaeodemographic findings of Jackes (1986) and Sullivan (1988). An additional indicator of the level of health in the children of Kleinburg is the frequency of non-specific periosteal lesions. Katzenberg (1992) noted a frequency of 31.1 % for the Kleinburg juveniles, assessing both left and right tibiae. Larocque (1991) found a frequency of 75.6% surveying the right tibiae only. Suffice it to say that each researcher was attempting to prove their own hypothesis, which may have accounted for some of the difference in observations. As noted with the Fairty tibiae, neither of these researchers assessed the entire sample, and as this may also be the case with the Kleinburg remains, no attempt is made here to address this particular pathology in light of the findings of no recognizable deficit in length of the long bones.

One final point must be made in regards to the findings from the Kleinburg juveniles. Although growth is said to be proportional amongst the limbs in the body, and indeed, reconstruction of stature from adult humeri has only slightly more standard error than from the lower limb bones, there is the possibility that a growth defect is not detected because the bones studied from this particular sample are the humeri. It may be possible that the femora and tibiae will show a growth deficit prior to the long bones of the upper body.

## **The Carton and Milton Ossuaries**

### ***The Teeth***

All of the mandibles with at least one or more deciduous teeth were culled from the two ossuary samples. Twenty three mandible portions from Carton were radiographed. These give a combined total of 25 individuals (complete mandibles plus left halves, plus two unfused infant hemi-mandibles). The MNI is derived from the right canines, and is sixteen. An additional seven exclusive mandible portions were not radiographed due to lack of extant teeth, bringing the total to 32 subadult individuals. This compares well with the number of individuals listed by a previous researcher, as 28 with mixed (deciduous and permanent) dentition (Yamaguchi pers com. in Hartney 1978: Table 50).

Twenty seven mandible portions were radiographed from the Milton Ossuary #1 collection. A combined total of 29 subadults is derived from complete and right mandible halves, plus two right infant hemi-mandibles. Five additional subadult individuals are represented by mandibular portions with no extant teeth, but these are not exclusive. A total number of 407 dental scores were entered into a database from both ossuaries.

Age at death was determined for each mandibular fragment by averaging the ages of all extant teeth, as was accomplished for the Fairty and Kleinburg samples. A total number of aged individuals was derived for the Milton Ossuary #1, and compared to the results of the original excavator and analyst. The comparative ages are presented in Figure 20 below.

## Milton Dental Ages

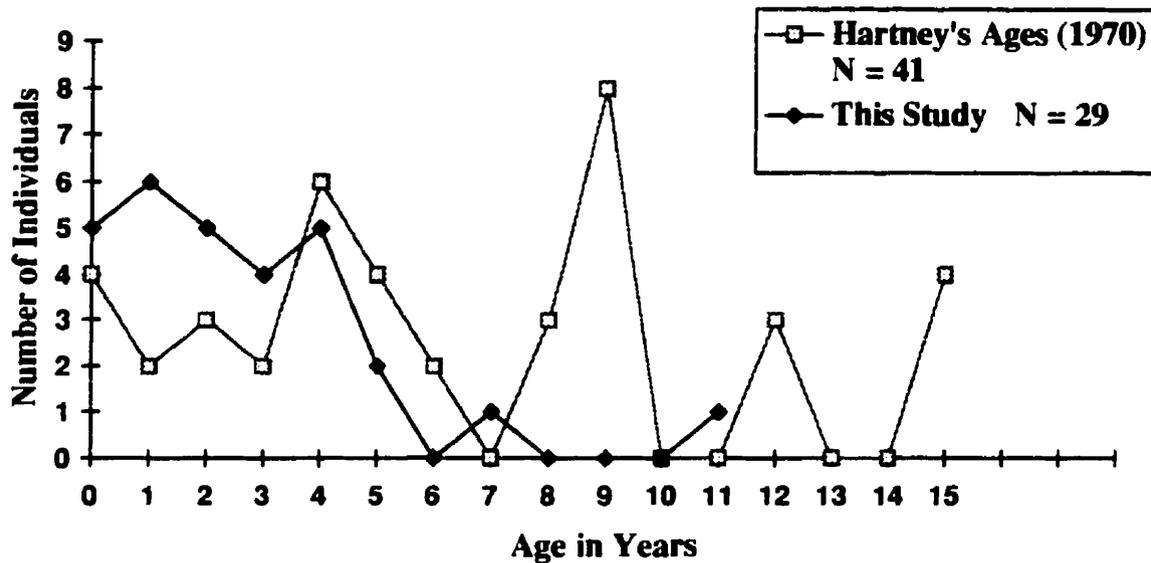


Figure 20: Line graph comparing the dental ages derived by Hartney (1980) utilizing the Schour and Massler (1941) standards to the dental ages derived from this study using the Moorrees et al. (1963a,b) standards on the Milton ossuary mandibles.

Hartney's table (1978: Table 128) lists 219 maxillary and mandibular items, of which 112 mandibular items are assigned an age using the Schour and Massler (1941) chart. His summary chart below gives a total of 65 mandibular items with deciduous and mixed dentition. Forty one of the items are given ages. These are reproduced in the graph above. If "items" referred to mandibular portions, or fragments, and not necessarily those which were mutually exclusive, then the count of 65 items compares well with a count done by this author (all portions unmended), which is seventy "items". If the two studies were looking at the same dentition, then the results presented above are extremely incongruous. The seven individuals older than eleven years would have had permanent dentition, and were not included in this study. The few individual disparities in the younger age groups can be explained by differences in the methods. The Schour and Massler method is based on dental eruption, and gives a wide age range (of which the mean was used to provide data for the graph above). The eleven 8 and 9 year olds are

unaccounted for in this study. Hartney states that there are 22 deciduous and mixed dentitions represented by the deciduous right second molar socket, in the body of his work (1978:209). It is, however, unknown which of the 41 aged fragments actually represent the 22 exclusive individuals. Similar problems have been encountered by B. Glencross when she has attempted to compare her minimum number of individual estimates to Hartney's. She has consistently arrived at lower estimates (B. Glencross pers. com.). We may only suppose that not all of the material was returned from the University of Saskatchewan, or that Hartney's original estimates were incorrect. Decoding what is represented in his tables is almost impossible. It was with this disparity in mind that the next phase of analysis was undertaken. No previous information for the Carton mandibles could be located, although a study does apparently exist (Yamaguchi pers. com. in Hartney 1978)

The two samples were combined, and both Spearman and Pearson correlation coefficients were run on all teeth for both sides and both sexes. The results for all teeth compared to the total average, and the mean by sex are presented in Table 15 below.

Tooth		Mean Age Female	Mean Age Male	Mean Age Sexes Combined
Left first deciduous molar	r <sub>s</sub>	.877 ***	.853 ***	.876 ***
	N	(15)	(14)	(15)
Right first deciduous molar	r <sub>s</sub>	.858 ***	.784 ***	.784 ***
	N	(15)	(16)	(16)
Left second deciduous molar	r <sub>s</sub>	.945 ***	.953 ***	.953 ***
	N	(9)	(9)	(9)
Right second deciduous molar	r <sub>s</sub>	.962 ***	.962 ***	.962 ***
	N	(9)	(9)	(9)
Left first permanent incisor	r <sub>s</sub>	.866 <sup>ns</sup>	Insufficient data	.866 <sup>ns</sup>
	N	(3)	(1)	(3)
Right first permanent incisor	r <sub>s</sub>	Insufficient data	Insufficient data	Insufficient data
	N	(1)	(0)	(1)
Left second permanent incisor	r <sub>s</sub>	Insufficient data	Insufficient data	Insufficient data
	N	(1)	(1)	(1)
Right second permanent incisor	r <sub>s</sub>	.258 <sup>ns</sup>	.775 <sup>ns</sup>	.775 <sup>ns</sup>
	N	(4)	(4)	(4)
Left permanent canine	r <sub>s</sub>	.936 ***	.946 ***	.936 ***
	N	(21)	(21)	(21)
Right permanent canine	r <sub>s</sub>	.975 ***	.971 ***	.978 ***
	N	(22)	(22)	(22)
Left permanent first premolar	r <sub>s</sub>	.923 ***	.939 ***	.931 ***
	N	(17)	(17)	(17)
Right permanent first premolar	r <sub>s</sub>	.926 ***	.939 ***	.912 ***
	N	(22)	(21)	(22)
Left permanent second premolar	r <sub>s</sub>	.954 ***	.955 ***	.955 ***
	N	(12)	(13)	(13)
Right permanent second premolar	r <sub>s</sub>	.937 ***	.937 ***	.912 ***
	N	(15)	(15)	(15)
Left permanent first molar	r <sub>s</sub>	.958 ***	.916 ***	.958 ***
	N	(13)	(13)	(13)
Right permanent first molar	r <sub>s</sub>	.710 *	.685 *	.685 *
	N	(10)	(10)	(10)
Left permanent second molar	r <sub>s</sub>	.975 **	.975 **	.975 **
	N	(5)	(5)	(5)
Right permanent second molar	r <sub>s</sub>	.848 ***	.882 ***	.815 ***
	N	(11)	(11)	(11)

ns = not significant

\* P ≤ 0.05

\*\* P ≤ 0.01

\*\*\* P ≤ 0.001

Table 15: Spearman Correlation Coefficient results for the combined Carton and Milton dental sample; each tooth by mean for sex, and sexes combined.

All of the teeth exhibit significant correlation, except for the incisors, where they are present. There are only three incisors in the sample, but the age values contributed by them were excluded from the final age determination.

### ***The Long Bone Diaphyses***

The femora and the humeri from the Carton ossuary were measured. Maximum diaphyseal length and proximal and distal end breadth were taken following Hoppa and Gruspier 1996 (Appendix A). The maximum number of individuals was counted on the left femora (N = 38), but of these, only 4 bones were complete, and an additional 11 were measurable by proximal end width. The right humeri were chosen for this study because they had the most numerous measurable portions (5 complete diaphyses and 10 proximal ends). The total number of measurable, and therefore ageable individuals is 15. The total number of subadults represented by diaphyses (38), compares quite well with the number represented by mandibles (31).

The Milton #1 ossuary was under analysis by B. Glencross at the time the data were taken. The humeral measurements (after Gruspier and Hoppa 1996) were provided to the author by Ms. Glencross. The maximum number of subadult individuals was counted on the left distal humeri and equals 35 individuals. Sixteen individuals were utilized for this study, and age determined from either diaphyseal length (7), or proximal end breadth (9). The subadult humeral diaphyses represent 4 more individuals than those represented by the mandibles.

These samples alone, and even combined are far too small to permit the derivation of an equation for predicting long bone length from diaphyseal end breadth, as was done for the Fairty and Kleinburg samples. Assuming a broad shared biological base for all of the populations was necessary. The equation derived from the combined Fairty and Kleinburg samples for prediction of diaphyseal length from the proximal end of the humerus was applied to this sample [ $- 19.624508 + 8.113157$  (proximal breadth)]. The two samples were combined for the reasons stated in Chapter 4.

The diaphyseal lengths from the left humeri were then transformed into ages using the standards of Merchant and Ubelaker (1977), and Maresh (1955). Mean ages were taken from those results presented as ranges. The age estimates for the combined Carton and Milton samples are presented in Figure 21 below.

**Carton and Milton Humerus Ages**  
**N = 31**

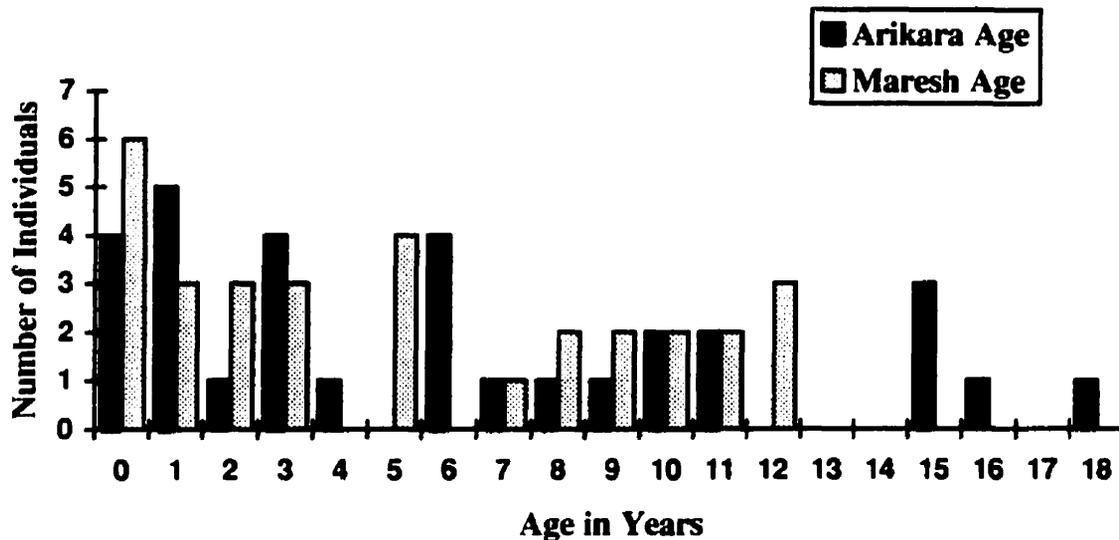


Figure 21: Bar graph depicting the distribution of the ages derived from the humeri for the combined Carton and Milton samples.

Neither the Carton, nor the Milton samples had any measurements below the lowest measurement for age interpretation for either the Merchant and Ubelaker (1977) or the Maresh (1955) standards, so loss of data was not a problem. Three individuals are aged 12 years by the Maresh method, two of whom are likely older as the diaphyseal length exceeded the diaphyseal length given by Maresh. After twelve years, Maresh (1955) gives long bone lengths including epiphyses. Five individuals above eleven years at death are noted using the Merchant and Ubelaker (1977) standards.

The sample size is too small to permit any meaningful statistical comparison of the methods for predicting similar ages.

### ***Inferences About Subadult Health and Growth***

The samples, even combined are far too small to posit any palaeodemographic inferences. It is unfortunate, as these small Neutral burial pits very likely did accurately represent the age distribution of deaths within the village with which they were associated. Additionally, Neutral villages were not inhabited for extended periods of time, and the dating of them is generally quite secure. Both Carton and Milton are tenuously dated however, and both of the burial pits had been disturbed.

Can any inferences about growth and health be made from these samples? The comparative age determinations are presented for number of individuals in Figure 22 and percent of individuals in Figure 23 below.

#### **Carton and Milton Dental Ages**



*Figure 22: Line graph depicting the distribution of the mandibular and humeral ages from the combined Carton and Milton ossuary samples.*

## Carton and Milton Estimated Ages: Percent

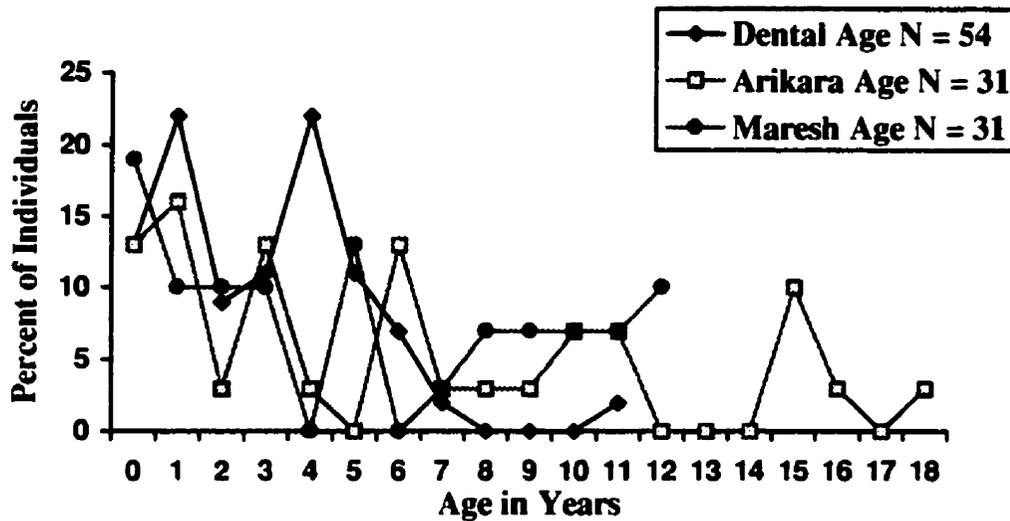


Figure 23: Line graph depicting the distribution of the mandibular and humeral ages by percentage from the combined Carton and Milton ossuary samples.

Figure 22 shows that the ages derived from the dental remains and those derived from the humeri appear to be exact opposites at any given age. The highest number of dental remains are aged at four years, while there is a single humerus aged by the Arikara method at the same age. Individuals are represented by humeri at ages 8, 9, and 10, but there are no dental remains aged the same. There are more dental remains than long bone remains, but this in and of itself does not account for the huge disparities. In order for the peaks of dental ages to be reflecting a biological reality (dental ages advanced over diaphyseal ages), there would have to be a corresponding peak in the lower diaphyseal age categories, and there is not. Figure 23 does not change the picture much except for that the dental and diaphyseal ages from birth to 3 years are in closer association with one another.

It was thought that a more accurate picture could be gained by looking at each of the samples separately. The results of the diaphyseal ages and the dental ages by percent for the Carton sample are shown in Figure 24 below.

## Carton Estimated Ages: Percent

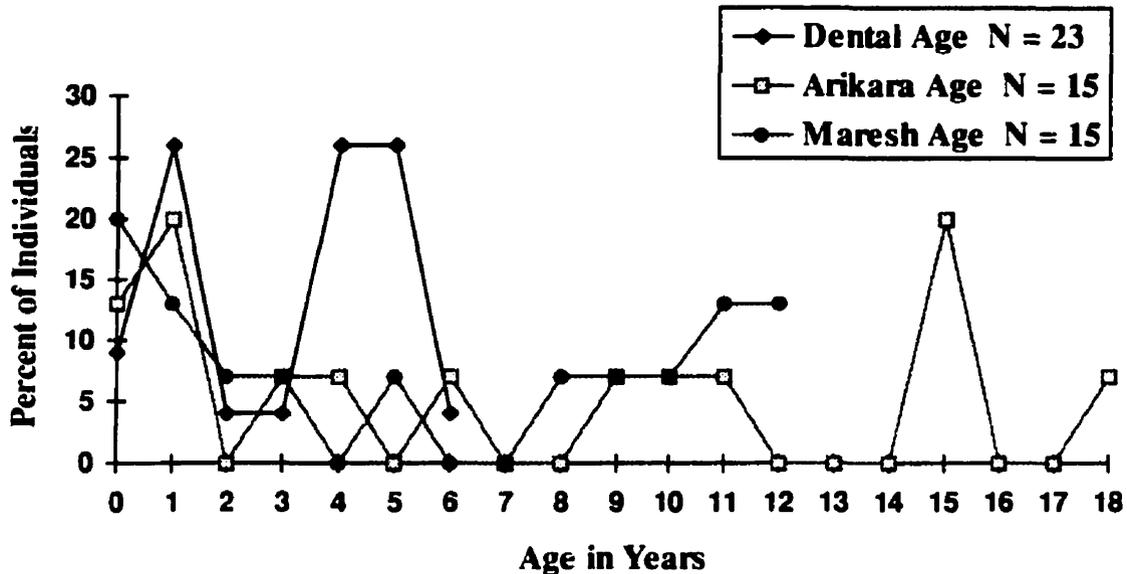


Figure 24: Line graph depicting the distribution of the mandibular and humeral ages by percentage from the Carton ossuary sample.

There is really not a lot which can be said about this. The dental ages are far more represented in the 4 and 5 year age categories. There are no individuals represented by dental remains past the age of six years, although the cut off for selection was approximately 10 to 11 years. There are only 3 individuals in those age categories represented by humeral diaphyseal lengths. It seems clear that the sample is biased. A maximum number of 38 subadults was derived from the femora, and 31 from the mandibular portions. Many of these could not be included in the database, so there is really nothing further that can be stated about growth or health from the Carton ossuary.

The Milton remains were assessed separately to see if any information could be gleaned from them (see Figure 25 below).

### Milton Estimated Ages: Percent

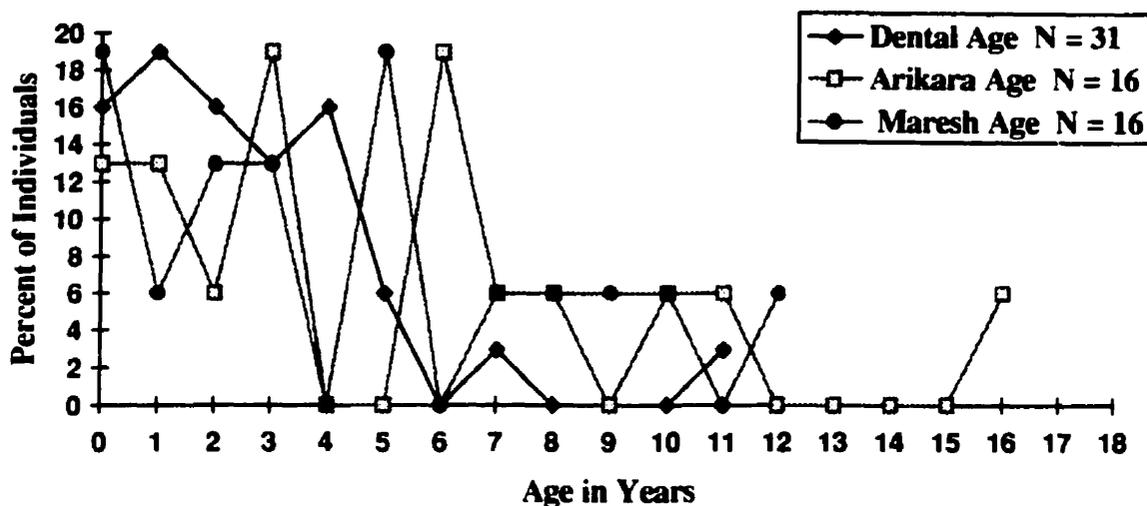


Figure 25: Line graph depicting the distribution of the mandibular and humeral ages by percentage from the Milton ossuary sample.

The picture from Milton is much the same as Carton. Neither set of aged data compares. In this case it is also that while all of the extant mandibles are aged, only 16 of the counted 35 humeri could be aged. The mandibles are therefore being compared to only half of the humeri. In much larger samples, like those of Fairty and Kleinburg, the missing individuals are not as obvious.

It is unfortunate that no good results can be derived from these two samples. The results of the age determinations, and what statistics could be performed are presented here in hopes that future researchers may find them of use for other studies. As stated in Chapter 3, the largest extant Neutral ossuary available for study is Glen Williams, which was irreparably damaged when all of the teeth were removed from the jaws. In so far as this study, or any further studies which must use dental calcification to derive age at death, there is no data.

# CHAPTER 6

## *Discussion and Conclusions*

### **Summary**

#### ***Environmental Bias***

A number of issues can be addressed from the preceding analysis of the subadult ages of the skeletal remains of the Carton, Milton, Kleinburg and Fairty ossuaries. First and foremost is the issue of environmental bias in preservation of remains. It is my contention, that with extensive and careful investigation into the circumstances surrounding the excavation, storage and previous analyses on a sample, all issues of environmental bias can be addressed. Original environmental bias may be more difficult to assess, unless the investigators make special note of the soil conditions (as with Carton), and unless they retained soil samples (only done for the Kleinburg sample). In this study, the looting of the Milton and Carton remains compounded the problem of a likely original, insufficient number of subadults for this type of analysis. These problems are further exacerbated by the Carton ossuary having been excavated by an amateur over a long period of time, and the Milton ossuary having been moved across the country and back. Environmental bias in these cases can mostly be defined as post-excavation impairment to sound interpretation of the remains. The Kleinburg ossuary was also subject to post-depositional and pre-excavation disturbance, although seemingly not on the order of the Carton and Milton ossuaries. The looting of the Fairty ossuary appears to have been minor from extant photos, but important information was lost when bundle burials of individuals were mixed in with the mass of disarticulated bone. The inexperience of the excavators in human osteology most likely accounts for this.

#### ***Cultural Bias***

Cultural bias has been addressed in Chapter 3. In the case of the Iroquoian treatment of the dead, there is a tantalizing reference which suggests that infants may be underrepresented in samples. The careful inventory and analysis of the Fairty material in

this analysis has shown this not always to be the case. There appear to be a large number of infants represented in the sample. A larger problem for demographic reconstruction from any ossuary skeletal sample is the fact that not everyone from a village will be re-interred in the ossuary. Ethnohistoric references cite the cases, but more compelling are the many incidental multiple interments and village burials which have been found. In order to assess the suitability of an ossuary sample for palaeodemographic inference, the careful analytical steps taken in this study must be adhered to, and only when the ages and sexes have been calculated, can the age structure of the population suggest whether the sample is truly representative of a living population or not. This then must be done on a case by case basis. Not all Southern Ontario samples are conducive to this type of analysis, and certainly not for intra-sample comparative purposes, as Jackes (1986) and Sullivan (1988) have done. Once the distribution of age at death has been obtained from a sample, it must be carefully assessed to be used in conjunction with other indicators of morbidity and mortality in a skeletal sample. Relating observations about demographics and disease derived from a skeletal samples to the living population from which it was derived is usually the next step in any complete skeletal analysis. Wood et al. (1992) have challenged how this is done, and even if it may be done. This is discussed in more detail below.

### ***Methodological Bias***

Saunders and Hoppa (1993) specifically state that the error in methodology of determining age at death for juvenile skeletons will far outweigh, and therefore obscure, any true biological growth deficit. The comparison of age determinations of dental remains from the Kleinburg ossuary is very encouraging as it addresses a form of error known as interobserver error. Three separate researchers determined the dental calcification ages of the Kleinburg mandibles, using different sets of x-rays, and different numbers of teeth. The results of statistical analysis show that for the most part, even though not all mandibles were included in each sample, the age determination results were similar. Consistent results can therefore be obtained between observers utilizing the Moorrees et al (1963a, b) dental calcification stages on the same sample.

A more important methodological bias is that inherent in the methods of age determination. The ages which can be determined using the present standards provide a mean with a variation of up to six months, which may well obscure slight changes in growth and development over 1 year age cohorts, and this is corroborated by Saunders and Hoppa (1993). A random sample of 50 individuals each from the dental and femoral data sets show that this is the case with individuals over the age of 2 years. In fact, the range of ages presented by the methods can far exceed 6 months on either side of the mean. The same cannot be said for individuals aged birth to 2 years. In these age cohorts, and even up to 3 years, the overlap rarely exceed 6 months on either side of the mean age, and very often it is less. This means that there is little chance of a child within these years being aged radically differently than his/her true age unless the long bones are the length of a child who would be expected to be much younger. At the present time, a statistical model to illustrate this observation is not available.

The Kleinburg remains suggest a growth deficit in the 1 to 4 year cohorts according to the findings of Saunders and Melbye (1990). This was not shown by a disproportionate number of humeri and dental individuals in the birth and 1 year group, as was the case for Fairty, but the percent of individuals aged by teeth in any one cohort (between birth to 4 years) always exceeded the percent of individuals represented by humeri. This difference does not appear to be statistically significant. The gauge used to suggest a growth deficit was percent cortical area. This, as stated previously, does not necessarily suggest severe malnutrition.

The Carton and Milton samples are not complete enough, either through environmental, or cultural bias to allow any observations on potential methodological bias.

### **Interpretations in Light of “The Osteological Paradox”**

It has been demonstrated that growth deficits can be quantified in ossuary samples, although it is a somewhat more difficult task than extrapolating the same information from samples with complete skeletons, and a robust statistical model for demonstrating this deficit has yet to be formulated. How can this growth deficit be

interpreted? Are extrinsic factors causing it, or is it an adaptive response and, therefore, non-pathological?

Wood et al. (1992) specifically address growth deficit (as well as other non-specific indicators of stress) on skeletal remains, and provide two alternative hypotheses concerning the transition to agriculture. The first is the widely accepted view (see the papers in Cohen and Armelagos 1984), that the observed increase in skeletal indicators of non-specific stress, and reduced mean age at death is a result of the adoption of agriculture and sedentism in prehistoric North American populations, and indicates a general deterioration in the health of these people. Wood and co-workers then suggest that the decrease in mean age at death could also indicate increased fertility (not generally an indication of deteriorating health), and that the increase in skeletal lesions of non-specific stress could suggest an improved ability to survive periodic disease episodes. They say that the data support either interpretation equally well. It is my assertion that both of these interpretations are far too simplistic. Perhaps if they are combined, they may more closely approach the reality. Their point that “using the archaeological record to infer health characteristics of a once living population is far more difficult than is commonly acknowledged” (Wood et al. 1992:357) is a good one, and they provide four suggestions for clarifying the relationship between what is observed on a skeleton, and what it may have meant to the living population from which it derived. These are outlined below, with comments on how Southern Ontario osteological analyses (including this one), have addressed them.

1. *Determination of sources of heterogeneity in frailty, both on a population and individual level.* This can never be adequately determined for archaeological populations, particularly those of Southern Ontario, where the prehistoric inhabitants never left any written records. Individual frailty cannot be addressed until the dead can be resurrected and asked about their health. The role of genetics and disease interactions can be more fully explored, but without the ability to derive an entire complement of genetic material from each skeleton in a study, any discussion of genetic frailty can never begin.

2. *Understanding of how a given frailty distribution is related to the distribution of risks of death among individuals (“selective mortality”).* While theoretical models may be possible based upon observations from modern disadvantaged countries, direct extrapolation from Southern Ontario prehistoric individuals is not possible, as we cannot resurrect the dead. We can however provide alternative hypotheses for interpreting findings from pathological and demographic observations on skeletal samples (as Wood et al. 1992 and Saunders and Hoppa 1993 have done). An attempt to do this utilizing the growth deficits from the Fairty and Kleinburg ossuaries is presented below.

3. *A better understanding of pathological processes.* This must be accomplished on documented specimens, and the information passed along to osteologists. This sounds somewhat simpler than it is. Disease in the living individual, when it is noted and diagnosed by an individual trained to do so, is usually treated (even in disadvantaged countries). When diseases are allowed to run their course without medical intervention, concluding in death or survival, this course is not documented by medical professionals as this practice is unethical. We must rely on historic descriptions of disease, and these rarely provide the depth of information necessary to give us a better understanding of a disease. My own observations, over a year of researching pre-antibiotic era papers on bone infection, uncovered many articles describing gross, chronic lesions (these are quite easily diagnosed in dry bone specimens), and few on “non-specific” periosteal lesions. This led me to conclude that individuals with diffuse periostitis on some skeletal elements were not necessarily clinically ill, as they had never sought diagnostic aid and treatment. This issue will be presented in more detail below, with regards to the findings, both published and derived, from the Fairty and Kleinburg ossuaries.

4. *Development of a better understanding of cultural context, and its role in determining selective mortality and heterogeneous frailty.* The cultural context of Southern Ontario prehistory and its evolution is slowly advancing. The development of theory is hindered by practical considerations surrounding the repatriation issue, and a moratorium on excavation of human remains. Monetary issues are also a big concern, as the funding rarely exists for large research projects or radiocarbon dating. Salvage operations, while usually reported upon, are not widely disseminated. The radiocarbon

dates for the Fairty ossuary have the potential to question a number of long held theories about the socio-political structure of populations contributing to ossuaries. This is discussed in further detail below.

### **Social Implications of Ossuary Burial in Light of Radiocarbon Dates for the Fairty Ossuary**

Ossuary samples are the most available collections for analysis of skeletal biology of the Iroquois. They have been systematically (or not so systematically) excavated for non-scientific or scientific pursuits from the last century. Anderson (1964:28) states that “at least 216 ossuary sites are known in the Province of Ontario”. Johnston (1979:91) points out that Anderson does not document these ossuaries, however some indication of location and content of these ossuaries may be gleaned from inventory sheets filled out by Anderson in the Department of Anthropology, University of Toronto’s archives. It does seem likely that Anderson was not exaggerating, as a brief survey through collections from Boyle, Wintemberg, Grant, Jury and Montgomery in the University of Toronto collections reveals many examples of multiple crania or artifacts retrieved from ossuaries in Southern Ontario. One only need survey the lists of acquisitions in the Annual Archaeological Reports for Ontario to see that others were engaged in similar pursuits. For example, the Annual Archaeological Report for 1918 lists human bones (accession # 37626), as a donation from a gentleman in Witchurch, Ontario. (Orr 1918: 129). These accession numbers can be traced to the Royal Ontario Museum. Another source of information (besides the writings of Boyle, Montgomery and others) which provides some information on the number of ossuaries opened or emptied in the past may be found in Wilson’s publication (1862). Daniel Wilson (later to become “Sir”) was a professor of History and English Literature at the University of Toronto. His two volume publication entitled “Prehistoric Man” contains a number of references to ossuaries and other Native burials. On his discussion of the origins of the material for a table he states;

“The measurements in Table IX are derived from thirty-eight crania obtained from Indian graves in the localities to the north of the water-shed, between Georgian Bay and Lakes Erie and Ontario ; and the greater number of them from ossuaries opened within the area lying between Lake Simcoe and Lake Huron.” (Wilson 1862: 269).

Wilson follows this table with one for the Iroquois ( a total of 10 skulls, deriving from Morton’s data, a collection in the Museum of McGill College, and a cast of Joseph Brant’s skull) (Wilson 1862:270). This is followed by a collection of data on 32 Algonquin crania from different sources (Wilson 1862:272). Further indications that a large number of ossuaries and burials were disturbed in the recent past is gleaned from comments such as;

“Of Indian skulls chiefly dug up within the district once pertaining to the Huron or Wyandot branch of the Iroquois stock, I had observed and cursorily examined a considerable number,..... Since then I have carefully examined and measured seventy-one Indian skulls.....” (Wilson 1862:263).

The main obstacle to utilizing these tantalizing references to “ossuaries” is that it is unclear what the writers and observers were referring to. How is an ossuary defined? Spence (1994) discusses this problem, and suggests the term “true ossuary” for those burial pits which contain large numbers of disarticulated individuals, with less indication of dismemberment. The “true ossuary” may represent a change in a community’s mortuary program, and would have been deposited only when a major shift in the community’s socio-political status occurred. Spence suggests that a village relocation, re-formulation of inter-village alliances or the death of a leader may have prompted this type of burial.

Largely due to the theories of Wright (1966), it was previously believed (and still is by some), that large ossuaries represented an evolution of the single and multiple burials seen in the Early Ontario Iroquois Stage (Johnston 1968, 1979), and are first seen in the Middleport Substage of the Middle Ontario Iroquois Stage (AD 1350 to 1400). Wright particularly notes Fairty as proof of this evolution. Fairty is may now be dated to the transitional Middle-Late Woodland, or Early Ontario Iroquois (Pickering) Stage, and as such, is one of the earliest true ossuaries in Southern Ontario, contemporary only with

Serpent Pits. Even if the radiocarbon dates are rejected, Fairty is still the largest ossuary to occur this early in Southern Ontario. Wright (1994) explains the non-conformity of Serpent Pits to this evolution as a special case, having been interred in an area that has a lengthy tradition as a sacred place. Further to this point, Wright maintains that there is a definite difference in Pickering and Glen Meyer burial practices, in that major burial sites away from villages are more characteristic of Glen Meyer. A total of three sites are mentioned in his argument, and none of these are large ossuaries (Rogers, Zamboni and Mac Allan). He states that there are no Pickering ossuaries situated away from villages, but in fact, the two largest ossuaries (Fairty and Serpent Pits) have no village associated with them [however, the proximity of the Faraday (½ km) and Robb (1 km) sites to Fairty may be interpreted as an association]. In the Middle Ontario Iroquois stage there are only three ossuaries; Tabor Hill (dated by its 2 km *proximity* to a Uren site), Middleport (dated to the site it was found near by Wright (1966), but not by the original excavators (Knowles 1937, Wintemberg 1948), and the recently excavated Moatfield (90 individuals very near a Uren village site). Middleport may not be a true ossuary, containing only 25 individuals, although Tabor Hill and Moatfield appear to be.

It is apparent, if one accepts the radiocarbon dates for Fairty, that Spence (1994) is correct in assuming that there is no “mortuary programme” for the Early Ontario Iroquois, and that social circumstances must have dictated whether people were left in the primary grave, disinterred to be placed in a small communal grave, perhaps once a year, or were disinterred to be added to a very large group of secondary burials, some retaining their individual personalities in a bundle, and others being mixed together. In addition, there does not appear to be a definable mortuary programme for the Middle Ontario Iroquois Stage either. The “true ossuary” is considered to be indicative of the Late Ontario Iroquois stage, both for the Huron and the Neutral (although the latter certainly engaged in other types of burial more frequently, to judge from the available archaeological record). The fact that the “true ossuary” was by no means the only mode of interment during this period has been noted by others (Dodd et. al 1990, Sutton 1988). Johnston (1979:100) notes that “The very large historic Huron ossuaries probably reflect special conditions arising from economic and political forces, disease and other

disruptive factors of the contact period". From the available evidence (c.f. Spence 1994 and Sutton 1988), it would appear that this was true of earlier periods also.

It follows then to ask; Who is buried in a true ossuary? Nearly every village site, regardless of period or tribal affiliation has some primary burials within or surrounding the houses. This suggests that not all the inhabitants of a village, or group of villages was disinterred for secondary burial in the ossuary. It has been suggested, that ossuaries are ideal for palaeodemographic reconstruction because they represent all of the dead of a village or group of villages over a specific time period (Jackes 1986, Pfeiffer and King 1980, Ubelaker ), usually approximately 10 to 12 years (surmised as the time of relocation of a village). These ideas came from the description of the Feast of the Dead and ensuing burial which took place at Ossossané in the spring of 1636 (Thwaites 1896-1901; Breb uf 1636:289, Biggar 1922-1936). The burial place was "outside of the village" of Ossossané, the village which was presumably hosting the event. Neighboring tribes were invited, and participated, one group coming from approximately 12 miles away (4 leagues) (Thwaites 1896-1901; Breb uf 1636: 291). The theory that the Feast of the Dead was given only when a village was to be abandoned, every 8, 10 or 12 years arises from the French observance that this was the amount of time a village was normally inhabited, coupled with observations about the St. Lawrence Iroquois feasts for the dead which in some cases had a different impetus, but also included abandonment of a village (here, specifically to inform the dead), for no particular reason after some number of years, and in times of public insecurity (Morgan 1901). Tooker (1964) notes that the Huron and Neutral probably elaborated the idea of informing the dead by way of a feast by combining it with their mode of ossuary burial. Fenton (1940) suggests that the Huron feast became more elaborate after contact.

Ossuaries should not be assumed to represent the dead of a single village from approximately a 10 year time period. Obviously (as stated above), other villages could have been, and were involved in bringing their dead to the secondary burial, and in the case of Ossossané, very many people attended (Biggar 1922-1936; Champlain 161-162, Sagard 1939:211). Additionally, re-location of the village was not the only reason for having a Feast of the Dead, and even this did not happen at known intervals. In sum,

each ossuary sample must be carefully assessed on the demographics of the individuals within it. The direct historical approach has assuaged the demographic theoretical enigmas which have plagued Southern Ontario osteologists for a long time, but it should not be so easily accepted that these ossuaries contain a defined group of people from a limited time period. Selective mortality is extremely difficult to assess under these circumstances. An alternative, more optimistic view is that we can be sure that the dead do not represent centuries of individual lives lived. The very fact that relatives were alive to recall where the primary interment or exposure was, and to be present to retrieve the remains for secondary reburial suggests that the Feast of the Dead, if it was going to occur, happened at least every generation.

The very large true ossuary (400 to 500 individuals) is not common, although some may have been lost in history, and others not found. The account of the Feast of the Dead at Ossossané states that it took place in 1636 (Thwaites 1896-1901; Brébeuf 1636:289). This was a mere 13 years before the Huron disappeared from Southern Ontario due to incursions by the New York Iroquois. We can surmise that the population was “stressed” at this time, having already been subject to internal warfare and European diseases and other damaging imports. Indeed, the recounting of the Feast of the Dead by Brébeuf is elaborate, almost appearing as if the Huron were trying to impress the French with the show. If these large ossuaries only occur as a result of extreme political stress, and include individuals from many villages, they cannot be assumed to be the normal type of burial, making demographic reconstruction from them (on the scale of Jackes 1986 and Sullivan 1988), almost certainly inaccurate. Estimations of morbidity, provided only by pathological indicators, and not survival and mortality rates, can however continue to be useful. Fairly must include the dead from a number of tribes or villages, as large villages are simply not known that early in prehistory (whichever date is chosen for the site). Kleinburg may well have included only the dead of a single village, as it is much more recent.

## **Juvenile Health in Southern Ontario: Alternative Interpretations**

### ***Fairty***

Katzenberg (1984) found that Fairty had relatively high strontium levels (in comparison to Kleinburg and Ossossané), similar to those of the Serpent Mounds burials. This indicates a diet that was not dependant upon low strontium foods (corn, barley, squash, tomatoes, cucumbers, mushrooms and others). She has some difficulty in explaining this, as Fairty was then thought to be dated approximately AD 1400, when the population would have been reliant upon corn. She suggests that removal of strontium from the samples through diagenesis may have contributed to the low strontium levels. In 1992, Katzenberg compared the results of carbon isotopes studies to her observations on the frequency of periostitis from both the Fairty and Kleinburg remains. She suggests that the Fairty people were heavily reliant upon maize, and that this is corroborated by the very high frequency of periostitis on the tibiae of the juveniles and adults. Laroque (1991) found a similar high frequency of periostitis on the juvenile and adult tibiae of the people of Fairty. Laroque concludes that as the lesions are mostly healed, the people of Fairty were healthy, and able to withstand infection. Katzenberg interprets all of her evidence as indicative of a highly stressed community, heavily reliant on maize horticulture, and therefore sedentary. She additionally suggests that the population density was high. Larocque (1991) also reports growth arrest lines for Fairty juvenile tibiae at 41% (almost half that of Kleinburg), and juvenile cribra orbitalia at 38% (similar to Kleinburg, and much lower than Ossossané at 9%). The presence of these lesions can also indicate well-adapted individuals who survived periodic stress episodes, or be indicative of very ill individuals (in the case of the cribra orbitalia) who died from stress-related illness. The low frequency of growth arrest lines in Fairty (In comparison to later sites) may indicate healthy individuals or those who showed no signs of surviving episodes of growth disruption, and therefore sickly individuals.

The results of this study show a growth deficit in the toddler age category (1 to 3 years). Growth deficits at this age are commonly seen in prehistoric North American skeletal samples, and are generally thought to indicate weaning age illness. Recent

chemical analysis to determine weaning age in past populations has provided some insight to this question. Most of the recent evidence has suggested that weaning itself does not cause increased infant mortality, but it is the introduction of other foods while still breastfeeding that is associated with increased juvenile mortality, if the individual is already living in a sufficiently poor environment. (Herring et al. 1998, Katzenberg et al. 1996). Specific studies of  $\delta^{15}\text{N}$  levels on Amerindian infant and child skeletons have suggested that infants received most of their dietary protein from breastmilk until 2 years of age (Katzenberg et al. 1996, Schurr, 1996, Tuross and Fogel 1994). This correlates with the 2 to 3 year period of breastfeeding mentioned in ethnohistoric sources (Charlevoix 1761:55, Thwaites 1896-1901; Brébeuf 1635:127).

I believe that all of the previous stress and nutrition data collected from the Fairty remains can be used to construct a different hypothesis. First we must assume that the chemical studies need to be augmented with additional studies and samples. Katzenberg's (1984, 1992, and 1993) studies on strontium, and carbon and nitrogen isotopes are conflicting, and the sample sizes are small. If one accepts the early radiocarbon dates for Fairty, it is unlikely that they were surviving on a mostly maize diet, although maize likely formed part of their diet. Additionally, the dates suggest that the population density could not have been that high, as large villages are not known from that period in prehistory. Habitation sites are generally interpreted as seasonal villages. Assuming this subsistence pattern, and a weaning age of between 1 and 3 years, the observed growth deficit could be considered as an adaptive response, as smaller bodies require less energy (Segraves 1977). The high frequencies of infectious disease and stress indicators simply indicate that the individuals were more able to withstand bouts of illness and dietary insufficiency, as Larocque (1991) concludes. They survived long enough for the disease/insufficiency to leave its mark upon the skeleton<sup>7</sup>. Finally, there is no evidence to suggest that periostitis, cribra orbitalia or other "stress" indicators are the result of disease which actually caused a person to be clinically ill. There is very

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<sup>7</sup> The theory that skeletons exhibiting numerous and chronic signs of stress in the form of periostitis, cribra orbitalia, enamel hypoplasia and other changes, were actually more adapted to their environment, and therefore more capable of surviving was first taught to me by Dr. D.J. Ortner at the Smithsonian Paleopathology short course in 1985. This theory has only slowly been accepted by other researchers in the field, and is the basis for Wood et. al.'s alternative hypotheses on juvenile stature and their reinterpretation of the transition to agriculture.

little in the medical literature on these conditions, most being descriptions of chronic bone infections (osteomyelitis) or anemic changes (cribra orbitalia and porotic hyperostosis) as the result of genetic anemia. This suggests even more that the skeletal responses are adaptive as opposed to pathological. This interpretation would be true if one accepts the traditional Middleport date for Fairty also. There would be increased reliance on maize, and increased sedentism, with more people contributing to the village, still, the response can be considered to be adaptive.

### ***Kleinburg***

Previously published data on the frequency of periostitis in the juveniles of the Kleinburg sample are consistent only in that the frequency here is less than that of the Fairty remains (Katzenberg 1992, Larocque 1991). Katzenberg interprets this as indicative of a better adaptation by the people of Kleinburg to sedentism and maize dependency, while Larocque states that the lesions are more often active than those seen on the Fairty remains, indicating that post-contact epidemics were affecting the people. Larocque also assessed growth arrest lines, cribra orbitalia and dental enamel hypoplasia (in adults only) in the Kleinburg skeletons. He found a very high frequency of growth arrest lines and dental enamel hypoplasia, and a rate of cribra orbitalia similar to that of Fairty. The elevated frequency of these stress indicators as well as the presence of more severe periostitis occurring less frequently fits well with Larocque's post-contact epidemic hypothesis. Collectively, the high or low frequencies of stress indicators and the lack of a longitudinal growth deficit, but the presence of a cortical bone deficit could either indicate a population well-adapted to their environment, or one in which acute conditions rapidly caused death. This has been explained above.

Other studies have been done on the Kleinburg remains in which different researchers have reported very different frequencies of disease from those reported here. Pfeiffer and Fairgrieve (1994) summarize most of these studies and point out the inconsistent findings while suggesting that it is impossible to draw any conclusions from the research. This is particularly true of studies on dental enamel defects and dental disease. My research failed to demonstrate a growth deficit in the juveniles of the

Kleinburg ossuary. A cortical bone deficit has been suggested from the work of Saunders and Melbye (1990), on the juveniles from Kleinburg, with a continuing deficiency into adulthood (Pfeiffer and King 1983). This has not, however, been demonstrated to be pathological.

One thing does appear to be clear; reliance on maize and sedentism with increased population density does not seem to be the only factor affecting the occurrence of indicators of stress. Theories based upon a shift in subsistence and settlement patterns, and introduction of new diseases are far too simplistic. It should be reiterated that these interpretations need not be necessarily extended to the population as a whole, but were definitely characteristic of the dead who were in the ossuary.

### **Future Research**

As with any research project, issues arise in the course of the research which cannot be addressed, or, may be more appropriate for answering certain questions. In addition, a good research project will always give rise to more questions than it answers. A number of areas of potential future research were identified in the course of this research, and they are outlined below.

1. Biochemical analyses: a) More samples must be analyzed by nitrogen isotope and elemental analysis in order to fix the age at weaning for these samples. In addition, more of these studies will help to elucidate which population samples were more reliant on maize, and to what extent, over time maize became more important in the diet. Excavated collections of Southern Ontario Native remains are being repatriated at an alarming rate, and research and research money should be directed to this type of research before it is no longer possible.
- b) Radiocarbon dating must be done on collections which have no relative method of dating. There are many problems with radiocarbon dates, and their accuracy, particularly from human bone, but numerous samples may minimize these problems. Again, research money must be found for this type of analysis.

2. **Investigation of adult stature and allometric and secular trends:** Although this study did not indicate that there were short individuals consistently throughout all of the age cohorts, there is a chance that the "stunted" individuals are not all abnormal. In order to investigate this further, the adult stature of all of the individuals in the samples should be calculated (note that this is presently being done by students under my direction for Fairty). Mean living height by sex can then be compared to the mean for modern and other pre-modern population samples. If the adults are consistently shorter, than it may be assumed that the children were consistently shorter throughout the age cohorts, accounting for at least some of the individuals who appear younger by diaphyseal length age than by dental age. In addition, recent research into the secular trend for stature has shown that there has been a trend towards increased stature from the time that the individuals from which the commonly used stature equations (Trotter and Gleser 1952, 1958) were derived lived, and the present time. In addition, this trend has been positively allometric with the lower limb bones, leaving the upper limb bones unaffected (Meadows and Jantz 1995). If this has been a trend which has been occurring throughout history as nutrition has improved, then it may have been normal for the population samples studied here to have had shorter legs in relation to the arms. If this were true in adulthood, then one would assume that it would also be detectable in childhood. This trend could account for consistently shorter children who would appear younger if aged by the femoral diaphysis (as with the Fairty sample). Similarly, the individuals would not appear to be consistently shorter than they ought to be if aged by the humeral diaphyses (as with the Kleinburg sample). This latter hypothesis cannot be easily tested with ossuary material where arms and legs are not matched up, and should be done on articulated burials. If either of these factors can be demonstrated, they will still only account for *consistently* short individuals across the age cohorts.
3. **Precise dental age determination:** There exist a plethora of methods for determining age at death by histological sectioning of adult teeth. The sections are either viewed microscopically, radiographically, or imaged in some way. A number of structures may be assessed and statistically manipulated to produce an estimate of age at death. In some cases, these methods may be more accurate at predicting age in adults than

skeletal methods of age determination, but this accuracy decreases after 30 years of age. The various methods and their percent accuracy are summarized in Hillson (1996). It is possible that histological aging of deciduous dentition may provide a more accurate age estimate for juveniles as well. In order to investigate this, teeth would have to be extracted both while forming and completely formed from children of known age. It is unlikely that a large enough database could be acquired without the inclusion of teeth from dead juveniles, and the collection of these teeth will prove difficult. Teeth with resorbed roots could be collected from living children when they fall out naturally. Amino acid racemization (specifically aspartic acid) has been shown to be of some utility in determining age at death from teeth (Gillard et al. 1990). Few studies have been done, and only on adults, where the error in years remains higher than  $\pm 6$  months. Further testing may find this method to be more useful.

## **Conclusions**

I believe that I have shown that there is compelling evidence to suggest that a growth deficit exists in the Fairty skeletal sample, specifically during the toddler years, and that this can be suggested in spite of the potential methodological problems. Equally, methodological problems have been minimized in demonstrating that a similar growth deficit does not exist in the Kleinburg juvenile sample. A study analyzing potential subadult growth deficits has never been undertaken on ossuary samples. This study has shown that certain problems with methodology can be investigated, specified, and controlled for within skeletal samples. Alternative interpretations to the meaning of these growth deficits have been offered, in concert with studies done by other researchers on indicators of non-specific stress, and gauges of the composition of diet. In order to clarify this apparent growth deficit, more research is needed on the samples themselves (statistical, biochemical and morphometrical), and the cultural milieu from which they derive (archaeological and radiocarbon dating).

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# **APPENDIX 1**

## Estimating Diaphyseal Length From Fragmentary Subadult Skeletal Remains: Implications for Palaeodemographic Reconstructions of a Southern Ontario Ossuary

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**KEY WORDS** Subadult, Long bone, Aging, Demography, Ossuary, Regression

**ABSTRACT** Fragmentary skeletal remains are a significant problem for osteologists attempting to reconstruct individuals or populations. This problem is further aggravated by sites yielding commingled remains, such as are recovered from the large protohistoric and historic ossuaries from southern Ontario, for which individual methods of age estimation and sex determination cannot be used concurrently. While some attention has been given to the estimation of long bone length from fragmentary, adult remains, little attention has been given to the equally important problem of fragmentary long bones in subadult assemblages. Analysis of data on diaphyseal length is a crucial aspect of reconstructing subadult palaeodemographic profiles, particularly for ossuary collections where dental remains are not associated with individuals and are often less represented than long bones. Such analysis also aids in the assessment of conditions of past population health. This study reports the results of several regression techniques used to estimate diaphyseal length from shaft-end breadths. Data collected from two southern Ontario ossuary samples were compiled to calculate the regression equations. Reliability of these equations and implications for palaeodemographic profiles are discussed. © 1996 Wiley-Liss, Inc.

The collection and analysis of data on diaphyseal length from subadult remains has two purposes. First, a variety of genetic and environmental influences, including malnutrition and disease, affect growth. As a result, skeletal growth profiles constructed from subadult long bone data can serve as nonspecific indicators of general health within a population (e.g., Stewart, 1954; Johnston, 1962; Walker, 1969; Merchant and Ubelaker, 1977; Sundick, 1978; Molleson, 1989; Lovejoy et al., 1990; Saunders and Melbye, 1990; Wall, 1991; Hoppa, 1992; Saunders et al., 1993; Miles and Bulman, 1994; Ribot and Roberts, 1996). Second, while the utilization of data on diaphyseal length to estimate individual ages can be

problematic (Hoppa, 1992; Ubelaker, 1987), in some circumstances, such as the large protohistoric ossuaries of southern Ontario, age estimation based on diaphyseal length is one of the few methods available for reconstructing subadult demographic profiles. A number of investigators have noted that when correlated with a good estimator of chronological age such as dental development, estimates of age based on diaphyseal length are the most reliable when dental data are absent (Hoffman, 1979; Sundick,

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1978; Ubelaker, 1989). Of course, all investigators would admit that such estimates are not as simple as this statement might suggest. The use of an appropriate skeletal growth profile must be selected on which to estimate age from diaphyseal length. However, built into such profiles are errors related to (1) variability in the timing of maturation within individuals and (2) environmental and genetic factors which can differentially influence the rate of growth and maturation in different populations (Hoppa, 1992). Ideally, all individuals should be included in demographic reconstructions so that the best representation of the individuals per age is attained. Unfortunately, such reconstructions are often based solely upon complete specimens, with fragmented remains used only to estimate a minimum number of individuals (MNI) within the sample.

Whether these sample profiles are representative of the population is a theoretical question that has undergone much debate recently (Hoppa, 1996; Saunders and Hoppa, 1993; Wood et al., 1992) and is not the focus of this paper. Underrepresentation, especially of infants and neonates, within skeletal samples as a result of differential preservation, burial practices, and excavation techniques has been a central focus of criticism within palaeodemographic reconstructions. It has been argued that the fragile nature of subadult skeletal material often makes for poor preservation in ossuary remains, which further reduces an often underrepresented cohort of the population (Kapches, 1976). As such, the younger the individual the more likely that the age cohort of that individual will not be representative of the general population (Johnston and Zimmer, 1989). However, "factors such as *differential burial practices and inexperience on the part of excavators* can prove more important to subadult skeletal preservation than differential tissue survival" (Saunders, 1992:2).

Although some attention has been given to the estimation of adult long bone length from fragmentary or incomplete remains (Steele and McKern, 1969; Simmons et al., 1990), little attention has been given to the equally important problem of fragmented

long bones in subadult assemblages (Gruspier and Hoppa, 1993; Hoppa, 1992). This report provides a method to estimate complete diaphyseal length from either the proximal or distal end of incomplete subadult long bones, and examines the implications of this technique for the subadult demographics of prehistoric southern Ontario ossuaries.

## MATERIALS AND METHODS

The primary data for this study were derived from two late Woodland, ossuary samples from southern Ontario: Kleinburg (MNI = 561; Pfeiffer, 1974, 1980) and Fairty (MNI = 512; Anderson, 1964). The Fairty ossuary is dated by association with the Robb site to between 1300 and 1350 A.D. (Kapches, 1981), although recent  $C^{14}$  results from the skeletal remains suggest an earlier date (Gruspier, 1996). The Kleinburg ossuary is dated by grave goods to 1580 to 1600 A.D. (Kenyon and Kenyon, 1983). Two smaller samples were used to test the cross-sample applicability of the regression equations: one is culturally and temporally similar to the reference samples, the other is not. The first is the Uxbridge ossuary, which dates from the late Woodland period of southern Ontario prehistory, falling temporally between Fairty and Kleinburg at  $1490 \pm 80$  A.D. (Pfeiffer, 1984). The second is from the cemetery site of Cosa, located in southern Tuscany on the west coast of Italy. The remains sampled for this study derive from the early medieval cemetery, tentatively dated to between the eighth and 10th century A.D. (Gruspier, 1994).

Both collections were thoroughly searched for all complete and fragmentary humeri and femora that exhibited unfused epiphyseal ends. Tibiae and radii were additionally sorted from the Kleinburg sample only. Neither of the collections had been previously fully mended, therefore this procedure was necessary before further analysis could proceed. Measures of proximal and distal shaft-end breadths were recorded for the humeri, radii, femora, and tibiae. Bones for each collection were sorted and grouped by side and preservation. Fragmentary remains were subdivided into proximal and distal frag-

ments for enumeration, and each specimen was checked for mends with all other fragments. This procedure was repeated for each bone. Diaphyseal lengths of all complete specimens were measured to the nearest millimeter using a standard osteometric board. Diaphyseal shaft-end breadths were recorded to the nearest tenth of a millimeter using Mitutoyo Digimatic calipers accurate to  $\pm 0.02$  mm. All measures were recorded independently by both authors to examine interobserver error and the reproducibility of the measurements. Definitions for each measure are as follows.

#### Humerus

**Proximal shaft breadth.** Holding the bone vertically with the proximal end up, and the caliper at a right angle to the shaft, place the fixed arm of the caliper *flush against the edge of the greater and lesser tubercles* and measure to the opposite edge.

**Distal shaft breadth.** Holding the bone vertically with the distal end up, and the caliper with the arms pointing downward, measure the maximum horizontal distance between the medial and lateral edges of the distal surface.

#### Radius

**Proximal shaft breadth.** Holding the bone vertically with the proximal end up, and the caliper at a right angle to the shaft, take a *maximum* diameter of the surface.

**Distal shaft breadth.** Holding the bone vertically with the distal end up, and the caliper at a right angle to the shaft, place the fixed arm of the caliper flush against the edges of the ulnar notch and take a measure to the opposite edge of the surface.

#### Femur

**Vertical head diameter.** This measure is a sagittal head diameter analogous to the measure taken on adult femora.

**Mediolateral neck breadth.** An additional measurement was obtained from the proximal femur in the Kleinburg sample, representing a maximum breadth, parallel to the shaft, from the growth surface of the head to the most lateral edge of the unfused

greater trochanter. This is *not* an oblique distance.

**Distal shaft breadth.** While holding the bone vertically with the distal end up, and the caliper at a right angle to the shaft, measure the maximum horizontal distance between the medial and lateral edges of the distal surface.

#### Tibia

**Proximal shaft breadth.** While holding the bone vertically *in anatomical position*, with the proximal end up, and the caliper at a right angle to the shaft, measure the direct horizontal distance between the medial and lateral edges of the proximal surface. This is not necessarily a maximum breadth.

**Distal shaft breadth.** Holding the bone vertically with the distal end up, and the caliper at a right angle to the shaft, place the fixed arm of the caliper flush against the edge of the fibular notch and take a measure to the opposite edge of the surface.

Initial analysis of the data included tests of equality for both sides and samples, as well as assessments of interobserver error for all the measurements. Following this the data were subjected to regression analysis. Linear and nonlinear models for estimating diaphyseal length from shaft-end breadths were tested for each measurement. Reliability of the estimates was examined through an analysis of residuals and by testing the equations on samples of complete bones. The final equations were then applied to a sample of incomplete long bones to estimate diaphyseal lengths. These estimates were then used to generate new subadult palaeodemographic profiles in both samples, utilizing the Arikara skeletal growth profiles (Merchant and Ubelaker, 1977). In order to test whether the equations are applicable for use in estimating diaphyseal length in other populations, they were applied to a sample of complete humeri from the Uxbridge ossuary, and humeri and femora from Cosa. The predicted lengths were then compared to the actual lengths of the diaphyses using paired samples *t* tests.

TABLE 1. Sample sizes and correlation coefficients between each measurement and diaphyseal length<sup>1</sup>

		Diaphyseal length	Prox1		Prox2		Dist1	
			N	r	N	r	N	r
Humerus								
Fairty	Left	88	77	0.9848			81	0.9823
	Right	90	82	0.9858			86	0.9838
	Combined	178	159	0.9854			167	0.9830
Kleinburg	Left	64	57	0.9438			58	0.9409
	Right	62	57	0.9570			54	0.9710
	Combined	126	114	0.9503			112	0.9557
	Total	304	273	0.9795			279	0.9789
Radius								
Kleinburg	Right	43	40	0.9741			30	0.9596
Femur								
Fairty	Left	89	70	0.9912			69	0.9813
	Right	86	64	0.9872			57	0.9721
	Combined	174	134	0.9887			126	0.9773
Kleinburg	Left	46	39	0.9787	38	0.9896	38	0.9515
	Right	43	33	0.9791	37	0.9886	32	0.9199
	Combined	89	72	0.9787	75	0.9891	70	0.9379
	Total	263	206	0.9869			196	0.9696
Tibia								
Kleinburg	Left	50	33	0.9777			35	0.9752
	Right	56	34	0.9754			38	0.9776
	Combined	106	67	0.9737			73	0.9766

<sup>1</sup>All correlations are significant at  $P < 0.0001$ .

TABLE 2. Independent *t*-tests for sides and samples

	N (L/R)	Mean diff. (mm)	SE mean diff.	<i>t</i>	df	2-tail sig.
Left vs. right						
Kleinburg						
Humerus	64/62	-3.6820	7.997	-0.46	124	0.646
Femur	46/43	14.7139	18.892	0.78	87	0.438
Tibia	50/56	-15.0086	14.104	-1.06	104	0.290
Fairty						
Humerus	88/90	-4.6707	9.136	-0.51	176	0.610
Femur	89/86	3.0865	15.578	0.20	173	0.843
Fairty vs. Kleinburg (sides combined)						
Humerus	178/126	-49.2728	6.055	-8.14	301.54 <sup>1</sup>	<0.001
Femur	175/89	-63.9887	12.208	-5.24	201.27 <sup>1</sup>	<0.001

<sup>1</sup>Levene's test for equality of variances  $P < 0.05$ .

## RESULTS

Table 1 presents the sample size for each measurement in the two ossuaries, as well as Pearson's correlation coefficients for each measurement with diaphyseal length, (PROX1 = proximal shaft-end breadth; PROX2 = neck length of femur; DIST1 = distal shaft-end breadth). Correlation coefficients calculated on each side independently result in slightly but not significantly higher *r* values. Independent *t* tests comparing both sides and samples for each measurement are presented in Table 2. While all measurements had comparable distributions for each side, comparison of the samples reveals that

Kleinburg has consistently larger mean values for each measurement.

Interobserver error was tested for each measure and the results are presented in Table 3. Paired samples *t* tests were used to evaluate the closeness of fit between each measurement for each author. The results suggest that some of these measurements are highly reproducible, but for others it is more difficult to obtain consistent results between observers.

Several regression models were applied to the data to derive prediction equations for diaphyseal length from measurements of shaft-end breadths. The complete diaphyses,

TABLE 3. *Interobserver error*<sup>1</sup>

Bone	Measurement	N	Corr.	2-tail sig.	Mean diff. (mm)	SE mean diff.	t	df	2-tail sig.
Femur	PROX1	67	0.998	<0.001	0.2582	0.060	4.29	66	<0.001
	PROX2	77	0.999	<0.001	-0.0221	0.074	-0.30	76	0.765
	DIST1	85	0.999	<0.001	0.1482	0.044	3.40	84	0.001
Humerus	PROX1	181	0.998	<0.001	0.0127	0.038	0.034	180	0.737
	DIST1	181	0.993	<0.001	0.0088	0.059	0.15	180	0.881
Tibia	PROX1	123	0.999	<0.001	0.0154	0.053	0.29	122	0.773
	DIST1	118	0.998	<0.001	0.1153	0.045	2.56	117	0.012

<sup>1</sup> Paired samples *t* test for each measure and bone.

TABLE 4. *Linear regression models and statistics*<sup>1</sup>

Bone	Measurement	N	R <sup>2</sup>	Adj. R <sup>2</sup>	a <sub>1</sub> (mm)	F	Signif F	Constant	β <sub>1</sub>
Femur	PROX1	205	0.97397	0.97384	17.00085	7632.08564	<0.0001	-39.566889	11.078994
	PROX2	74	0.97824	0.97794	12.55510	3281.15766	<0.0001	-70.276137	4.935822
	DIST1	195	0.94021	0.93990	24.78380	3050.48616	<0.0001	-41.059877	5.959925
Humerus	PROX1	272	0.95948	0.95933	12.17259	6416.56373	<0.0001	-19.624508	8.113157
	DIST1	278	0.95834	0.95819	12.24649	6371.49155	<0.0001	-31.555209	5.971567
Radius	PROX1	39	0.94880	0.94745	9.96877	704.11793	<0.0001	-27.038659	13.432445
	DIST1	29	0.92077	0.91794	13.15042	325.41150	<0.0001	-31.721254	9.561292
Tibia	PROX1	66	0.94800	0.94720	16.53400	1184.92399	<0.0001	-43.848220	6.126475
	DIST1	72	0.95381	0.95316	16.34698	1466.29196	<0.0001	-58.862430	10.307365

<sup>1</sup> Adjusted R<sup>2</sup> = R<sup>2</sup> -  $\frac{K-1}{n-K}$ (1 - R<sup>2</sup>) takes into consideration the complexity of the data compared to the complexity of the model (Hamilton, 1992) and provides a more realistic estimate of how well the model fits the population (Norušis, 1993). Goodness of fit for the equations is assessed by the residual standard deviation,  $a_1 = \sqrt{\frac{RSS}{n-K}}$ , where *n* is the sample size and *K* is the number of parameters.

sides pooled, for both samples were combined. The regression equations and their test statistics are presented in Table 4. Graphs were generated to illustrate the relationship between diaphyseal length and each of the shaft-end breadths. Figures 1–3 illustrate the relationship between diaphyseal length and each measurement for the femora and humeri, with linear regression lines and their 95% prediction intervals overlaid. All measurements demonstrated a strong correlation with diaphyseal length, exhibiting a near-linear or slightly curvilinear distribution. Goodness of fit statistics and residuals were examined to test the validity of the linear models. Figure 4 presents a residual plot for one of the equations. The results of these suggested that samples which contain a considerable number of neonatal/fetal remains are better fitted by a polynomial equation (Fig. 5).

Testing the accuracy of these models for other population samples was conducted by applying the regression equations to a small sample of complete bones from the Uxbridge ossuary and the Medieval Italian cemetery at Cosa. The results of the paired samples *t* tests used to evaluate the degree of deviation between the observed and predicted lengths are presented in Table 5.

Subadult palaeodemographic profiles were subsequently generated from the long bone sample, including both complete and estimated diaphyseal lengths. Individuals were placed in 1 year age categories by length, based on the Arikara skeletal growth profiles (Merchant and Ubelker, 1977). The refined mortality distribution for the Fairty ossuary, including fragmentary remains, is presented in Figure 6. This demographic profile is based on the right humerus with fragmentary lengths estimated from distal

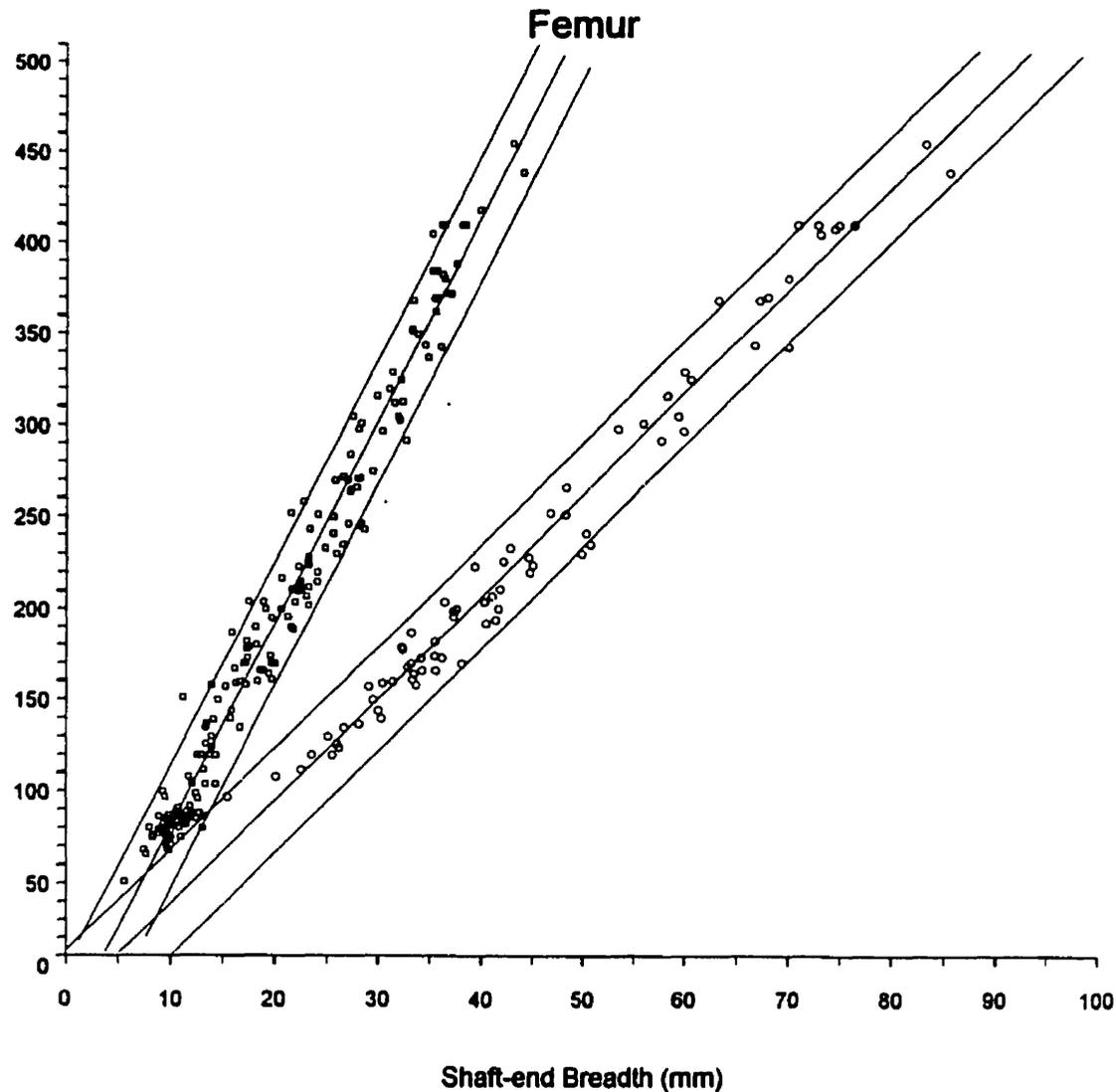


Fig. 1. Scattergram of shaft-end breadths for the femur (PROX1, squares; PROX2, circles) vs. diaphyseal length. Linear regression lines of the form  $Y = \beta_0 + \beta_1 X$  and 95% prediction intervals are overlaid.

shaft-end breadths. Inclusion of individuals represented only by incomplete long bones increased the sample size by over 100%.

#### DISCUSSION

To estimate complete lengths from fragmentary remains, it is important that accurately recognizable landmarks be used. As a result, the measures used to develop regression models for diaphyseal length are limited. Measures of breadth along the shaft

are inappropriate as differential fragmentation may prevent or inhibit proper and accurate identification. Therefore, the only remaining locations suitable for measurements on fragmentary remains are the epiphyses and the ends of the diaphyses or metaphyseal regions. Since ossuary collections are not normally conducive to associating bones for unique individuals, the use of epiphyseal measures is not universally applicable, although it can be done (Hoppa,

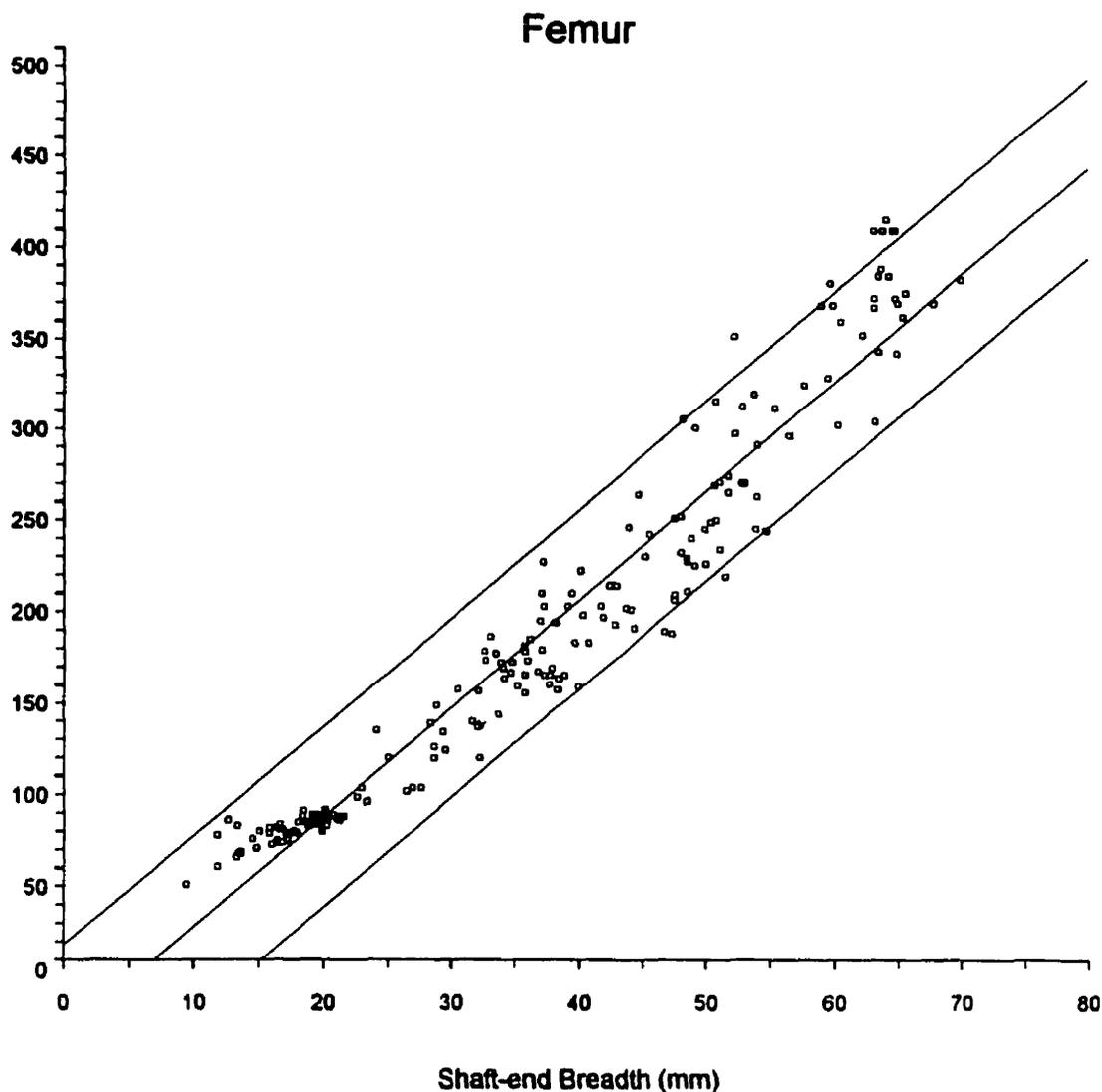


Fig. 2. Scattergram of proximal shaft-end breadth for the femur (DIST1) vs. diaphyseal length. Linear regression line of the form  $Y = \beta_0 + \beta_1 X$  and 95% prediction intervals are overlaid.

1992). The results for interobserver error in Table 3 indicate that some of the measures are less reproducible than others. However, given that all measures were taken only to the nearest tenth of a millimeter, and that the mean difference is always less than this level of precision, the difference is of no consequence either practically or theoretically (Brown and Rothery, 1993).

As with any statistical procedure, there are a number of assumptions built into ordinary least squares regression analysis that

should be addressed. Since most of these assumptions focus on error (omitted variables, a nonlinear relationship, nonconstant error variance, correlation among errors, nonnormal errors, or influential cases), residual analysis is one way of assessing these problems. Normal probability plots of residuals and scatter plots of predicted values vs. residuals aid in assessing the validity of these assumptions (Hamilton, 1992). Figure 4 presents a residual scattergram for one of the regression equations presented here. It

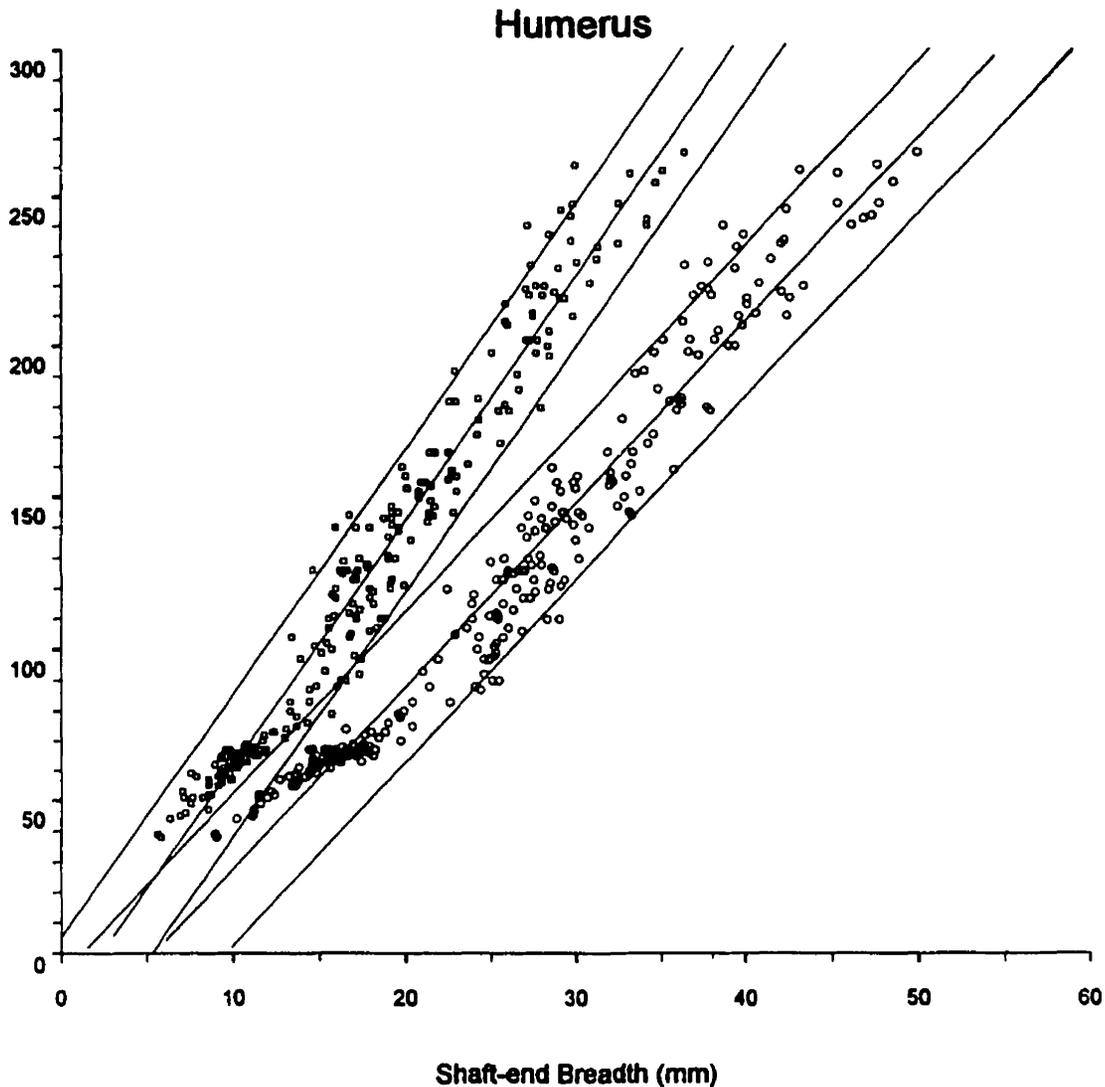


Fig. 3. Scattergram of shaft-end breadths (PROX1, squares; DIST1, circles) for the humerus vs. diaphyseal length. Linear regression line of the form  $Y = \beta_0 + \beta_1 X$  and 95% prediction intervals are overlaid.

is clear from this graph that the error is normally distributed and relatively homoscedastic (the magnitude of error is constant), and there are no influential cases. The slightly nonnormal distributions of neonates, as denoted by the majority being found with negative residuals, does suggest a slightly nonlinear relationship with the inclusion of very young individuals. For the humerus this was more apparent as a result of increased numbers of perinatal humeri

being included in the sample. As a result, second and third order polynomial models were also generated which more precisely modeled the relationships (Fig. 5). The overall residual standard deviation ( $s_e$ ) for these models is not significantly reduced since the residuals tend to be improved only in the very small perinatal remains. For the majority of the sample, the scatter around the regression line remains essentially the same as the simple linear equation.

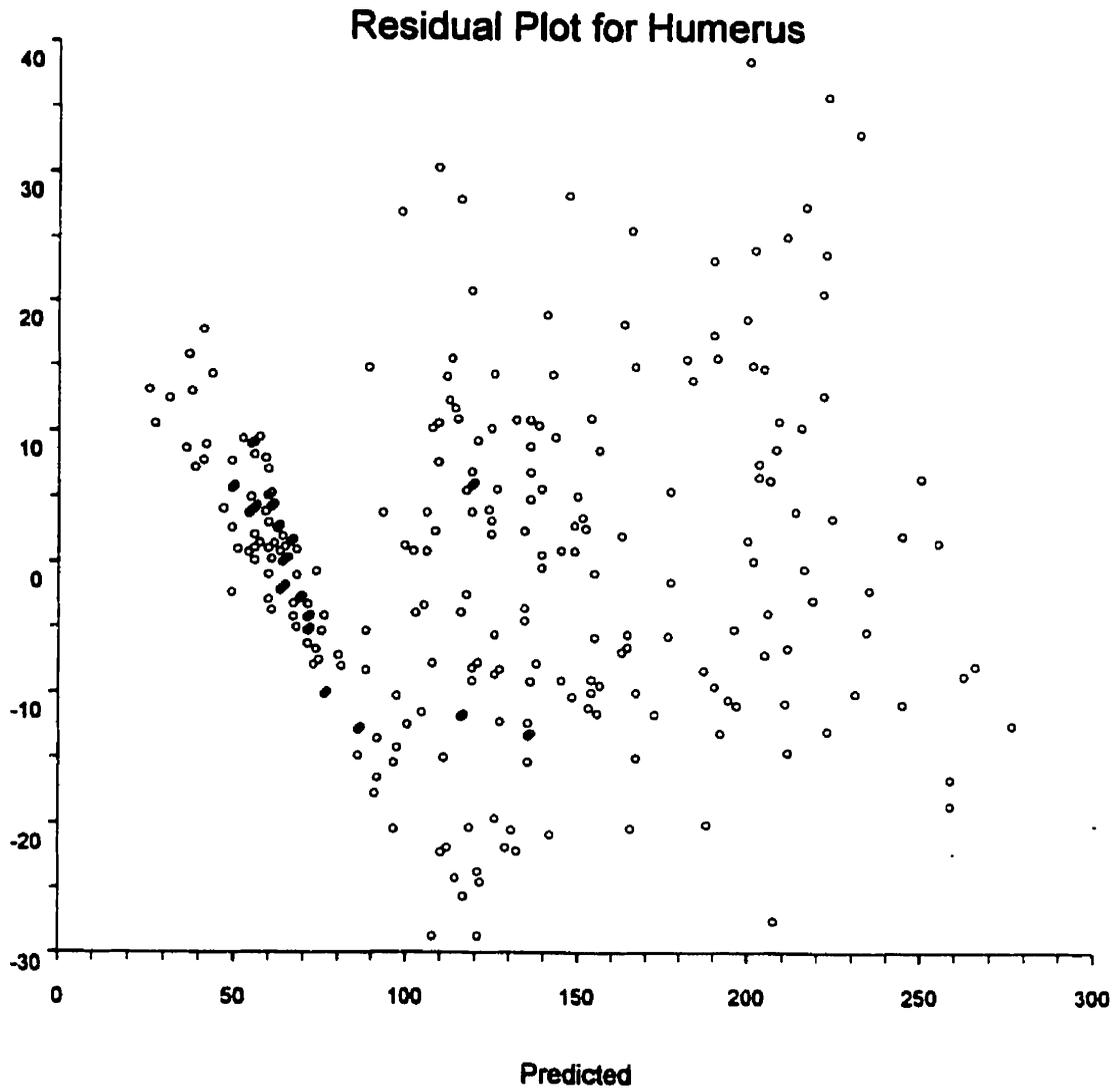


Fig. 4. Residual plot for the linear regression equation for humerus (PROX1). The plot shows a relatively random distribution of error with the exception of the very small bones, which tend to be consistently underestimated by the linear equation.

An earlier study of this method (Hoppa, 1991) assumed that the process of bone growth would be similar within any human subadult series regardless of ethnic or cultural origins, and that such data could be pooled to derive an overall relationship between the various measures. This initial study included subadults from both a 10th century A.D. Anglo-Saxon collection and a 4th–5th century A.D. Romano-British collection, and found reasonably good correlations

between shaft and epiphyseal breadth and diaphyseal length ( $r$  values ranging from 0.86 to 0.96). However, subsequent separation and independent examination of the two samples revealed significant differences, with the extraction of the Roman remains increasing the correlation coefficients for the Anglo-Saxon sample. This suggested that differences between samples may be significant and that population-specific models might be necessary to make accurate use of

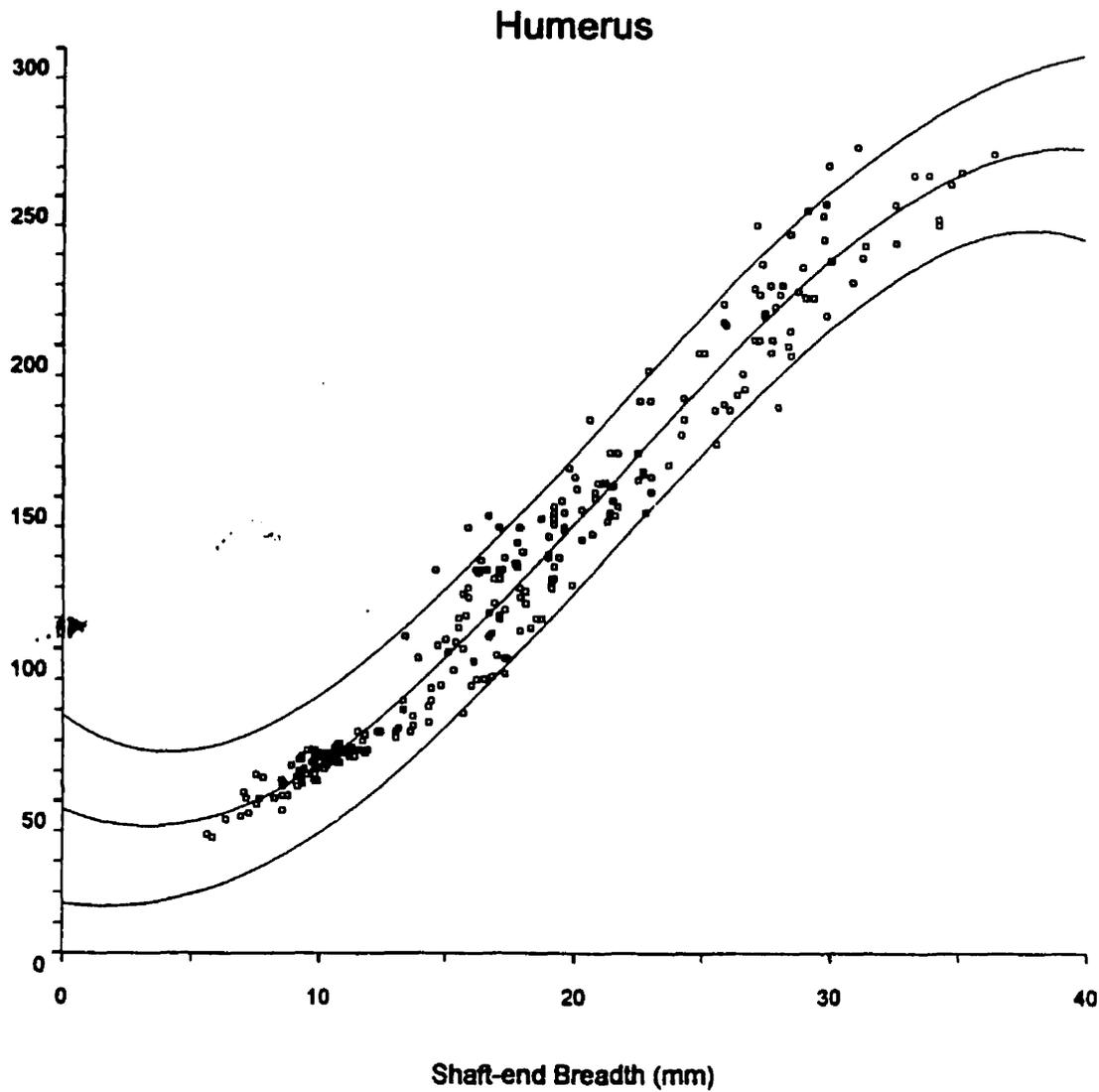


Fig. 5. Scattergram of distal shaft-end breadth for the humerus (PROX1) vs. diaphyseal length. Cubic regression line of the form  $Y = \beta_0 + \beta_1X + \beta_2X^2 + \beta_3X^3$  and 95% prediction intervals are overlaid.

TABLE 5. Paired samples *t* tests of observed vs. estimated diaphyseal length

Bone	Estimator	Mean diff. (mm)	SD diff.	<i>t</i>	df	<i>P</i>
<b>Uxbridge</b>						
Humerus	Prox1	-3.237	11.392	-1.927	45	0.060
	Dist1	-4.908	9.279	-3.777	50	<0.001
<b>Cosa</b>						
Humerus	Prox1	3.006	14.776	0.839	16	0.414
	Dist1	-5.056	12.661	-1.597	15	0.131
<b>Femur</b>						
	Prox1	-24.305	35.692	-2.968	18	0.008
	Dist1	-13.720	29.089	-2.109	19	0.048

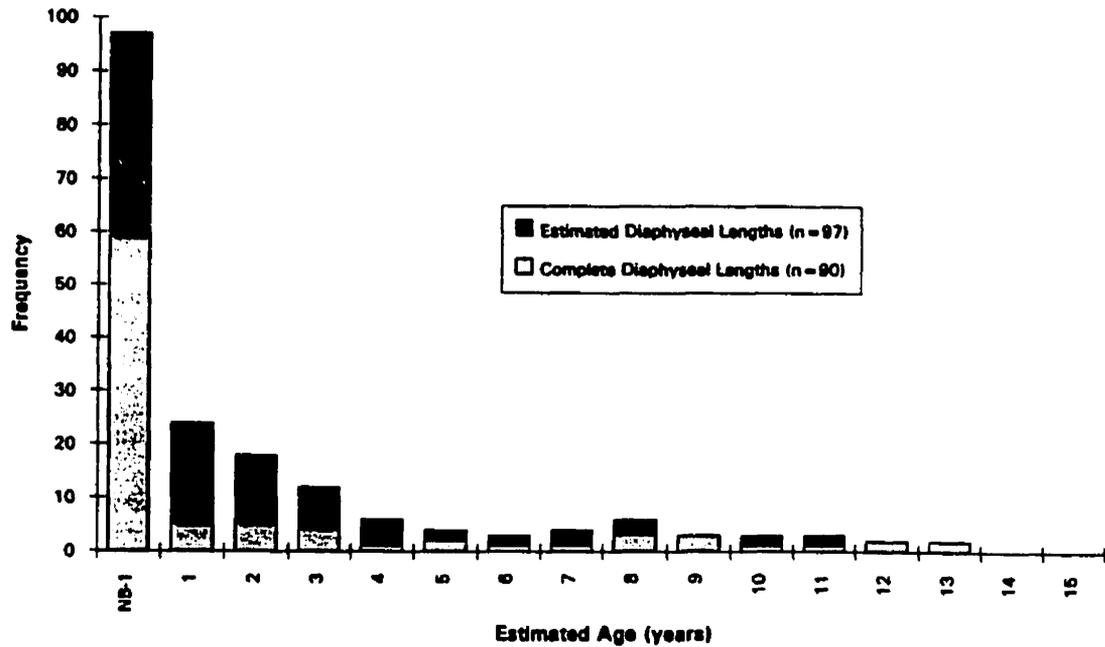


Fig. 6. Subadult demographic profile for Fairy, illustrating the impact of the inclusion of individuals represented by fragmentary remains. The demography is based on the right humerus, with fragmentary remains estimated from distal shaft-end breadths.

these methods. This finding is supported by this study, which observed significant differences between the two late Woodland samples, due primarily to the preponderance of perinatal remains in the Fairy sample. Despite this, the samples and sides were pooled for the final presented equations, since examination of residuals for side- and site-specific equations applied to their complementary holdout sample produced error distributions comparable to that observed using the combined-samples equations. That is, the actual level of predictability did not significantly improve when using a single reference sample. The final equations were also tested on two small samples of complete bones: one southern Ontario sample and one Medieval Italian sample. The results of the intersample tests for accuracy are not that surprising. Despite being relatively close in temporal and cultural affiliation to the reference sample, prediction on the Uxbridge sample produced mixed results, with significant or near-significant differences observed. The fact that for the Cosa sample

the predicted humeri lengths are not significantly different from the observed lengths, while the femora are, suggests that differential growth in the limbs for different populations may further complicate interpretation of the results. Another factor to be considered is the general level of health within populations, particularly those childhood conditions which can affect growth. For example, in the Cosa sample almost all of the subadults exhibit multiple indicators of non-specific stress (Gruspier, 1994). In fact, it would be of interest to explore whether or not application of these equations to other samples of complete bones could be used to identify individuals that are pathological. Given that interruptions in the growth process tend to affect the overall length of a bone and not the width at the ends, large deviations between predicted and observed lengths may suggest this. Although the application of our equations does seem to produce estimated lengths that do not always differ significantly from known lengths in both samples, we would still encourage other

investigators to create their own sample equations when possible.

The potential of this technique for maximizing the sample size of the subadult cohorts is clearly illustrated in Figure 6. The profile created for the Fairty ossuary shows an increase in sample size by over 100% when the estimated diaphyseal lengths are included. An earlier study (Larocque, 1991) reports that, for the Fairty ossuary, 43% of the total sample of 512 individuals are less than 20 years of age, and of those 35%, or about 77 individuals, are under 3 years of age based on the tibiae. In the present study, we find a comparable count ( $n = 72$ ) of individuals under 3 years of age based on the complete humeri (right side only). However, the inclusion of the fragmentary humeri results in an *additional* 97 under 15 years of age. Most importantly, the greatest increase is seen in the under-5-year-olds, which represent the age cohort most useful in interpreting the overall health of a population. Ironically, it is this cohort that is most often statistically manipulated (Jackes, 1986; Melbye, 1984) or simply ignored (Jackes, 1994) in demographic analyses of southern Ontario ossuaries. This circumstance is due in part to the misperception that *all* southern Ontario ossuaries are lacking in infant skeletal remains (e.g., Jackes, 1994; Kapches, 1976; Katzenberg and White, 1979; Sutton, 1988). However, in their paper, Saunders and Spence (1986) discuss underrepresentation specifically with regard to late fetal and perinatal infants. With regard to postneonatal infants, "presumably, the bulk of infants dying during the postnatal period were buried in the ossuary" (1986:52).

Although we recognize that there may be some variability in age assessments based on estimated diaphyseal length, it is clear that a substantial number of infants and young children were underrepresented in the Fairty ossuary demography as a result of methodological bias. It should be noted, however, that the inclusion of these individuals does not increase the overall MNI calculated by Anderson (1964), which were derived from counts of mastoid processes.

### CONCLUSIONS

Given the potentially rich source of demographic information available in southern

Ontario, a number of studies (e.g., Montgomery, 1886; Hammond, 1923; McIlwraith, 1946, 1947; Kidd, 1953; Churcher and Kenyon, 1960; Anderson, 1964; Katzenberg and White, 1979; Pfeiffer, 1974, 1983; Jerkic, 1975; Saunders, 1977; Hartney, 1978; Molto, 1983; Patterson, 1984; Jackes, 1986; Mullen, 1990; Mullen and Hoppa, 1992; Gruspier, 1996) have focused on skeletal samples derived from ossuaries.

"The Ontario Iroquois ossuaries, especially those of the Huron, are particularly amenable to demographic analysis because, due to historical accident, the problems of sample size and chronological control do not apply" (Katzenberg and White, 1979:11).

Although there has been some recent criticism of the exact degree of chronological control we can assume for large ossuaries (Sutton, 1988), they still represent a potentially valuable source for demographic analysis because of the sheer quantity of material available. However, in some earlier analyses, much of the fragmentary bone was considered unanalyzable and was not included in the resultant demographic profiles. In the case of southern Ontario ossuaries, the method of interment, which promotes increased fragmentation of bones, may contribute to the inaccurate representation of the subadult demographic profile. As Young and Varley (1992) note, during the later period of ossuary evolution in southern Ontario, there is a shift in structure of the ossuary from the maintenance of individual burials to the thorough mixing of bones. The following ethnohistoric account illustrates the potential for fragmentation of bones as a direct result of the manipulation of the remains in the ossuary during the ceremony of the Feast of the Dead.

"The bones were to be thrown into the pit at daybreak. . . emptying the packages into the pit but keeping the robes in which the bones were wrapped. Five or six in the pit arranged the bones with poles as they were thrown in" (Thwaites, 1896-1901:vol 10: 299).

Although the lack of inclusion of fragments may have less effect on the adult demography, a subadult fragment may represent a substantial portion of a single bone—the equivalent of a single individual. It is clear from this study that the exclusion of frag-

mentary remains can have drastic effects on paleodemographic reconstructions. As we recognize the potential error inherent in making individual estimates from regression equations, the mortality distribution we present represents not absolute age cohorts, but rather the impact on palaeodemography of omitting fragmentary skeletal elements. Whether infants are underrepresented because of fragmentation or omission from the sample, there will still always be subadult fragmentary remains which cannot be aged without some method of estimating their complete lengths. This study provides a technique for this purpose with regression equations for measures of proximal and distal shaft-end breadths used to estimate diaphyseal length.

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