2003

Premortem tooth loss : a model for estimating adult age at death

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Premortem Tooth Loss: A Model For Estimating Adult Age at Death

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Submitted in partial fulfillment of the requirements for the Degree of Masters of Arts
University of Montana 2003

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5-27-03

Date

Medved, Dawn M., M.A., May 2003 Anthropology

Premortem Tooth Loss: A Model for Estimating Adult Age at Death (61 pp.)

Director: Thomas A. Foor TAF

This thesis investigates a skeletal sample that is gender and race specific. The sample contains a review of the full dentition of 237 black females from the Hamann-Todd Skeletal Collection. These materials are permanently housed at the Cleveland Museum of Natural History. The sample was examined macroscopically for acquired dental pathologies, (i.e., premortem tooth loss (PMTL), necrotic crowns, peri-apical abscesses, root fragments, caries, developmental anomalies and dentistry). The primary focus was on PMTL. Data were colleted as a binary system of relations, characteristic of either each tooth being present or absent within its respective alveolus. The goal of the assessment was to determine if adult tooth loss in humans was age-related and if this was found to be true-- how patterns of tooth loss relate to an estimate of age at death. This information was then statistically evaluated in regard to satisfying a multivariate analysis. The analysis did support a regression variate that successfully contributed to assisting in age at death estimations.

Acknowledgements

I am thankful for the support given to me by my thesis committee. The guidance from Dr. Thomas Foor has been a true delight as his advice was invaluable in keeping this thesis focused. Thanks to Dr. Noriko Seguchi for extending such enthusiasm and for her expertise concerning dental anthropology. Her insight was vital in easing the transitions within the thesis. To Dr. Rodney Brod I extend gratitude for his patience concerning my inquiries and for sharing his intellect over the duration of this endeavor. His encouragement was key in helping me tackle the rudiments of statistical analysis--as he has a rare sense for making statistics tangible. Of course, to have initiated and continued with the entirety of this pursuit is truly a result of the formative education I received from Dr. Robert P. Mensforth of Cleveland State University. Dr. Bob's superior mentoring capabilities have continued to prepare me for the professional world and I will always value the integrity of our friendship. In addition, I thank the Cleveland Museum of Natural History for allowing me to pursue curation and data collection-- in aiding Lyman Jellama I initially overcame any latent inhibitions to pursue investigative measures. Lyman's continued support and jolts of spunk are ideal! I also wish to thank my family for their spiritual and loving support, the folks at the Montana Crime Lab for their concern with the project's completion, Scott Haver- CSU Instructional Computing and JoAnne Allen for their generosity in keeping me sane through all the encountered computer glitches, Frank Jablonski for proofreading, Kenyette Barnes-Harper for keeping in check with our mutual academic progress along with our soul connections, Thomas Boyce for absorbing all my explanations and questions from the start and the Lord for watching over me.

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<u>Chapter 1: Introduction</u>

Anthropological and forensic science studies have long considered oral anatomy, inclusive of the human dentition, as useful biologic structures in positing "interrelationships between host and environment" (Sognnaes, 1960). Through the ages an array of scholars, anatomists and pathologists have focused their interest on teeth, teeth have remained within the research agenda across disciplines (Brekhus, 1928; Hellman, 1936; Dahlberg, 1945, 1966; Gustafson, 1950; Szabo, 1959; Garn & Lewis, 1962; Miles, 1963; Johanson, 1971; Levine, 1972; Dermirjian et al. 1973; Bang, 1989; Solheim, 1993; Hildebolt and Molnar 1991; Vystrchova and Novotny, 2000).

In particular, teeth exhibit durability. This relative durability is fundamental when researching teeth and aging. Unlike bone, a tooth consists of dense connective tissues arising from the skin or dermoid system. Through the process of tissue generation both ectodermal and mesodermal cells create the stable elements innate to a tooth (Sognnaes, 1960).

An important component of a tooth is its surrounding layer of enamel. **Refer to Figure 1.** Enamel is thickest at the proximal end of a tooth, where it forms a shield, while it becomes thinner toward the neck. Underneath the crown, within an inner chamber, a tooth forms dentin (Sicher & Dubrul, 1975).

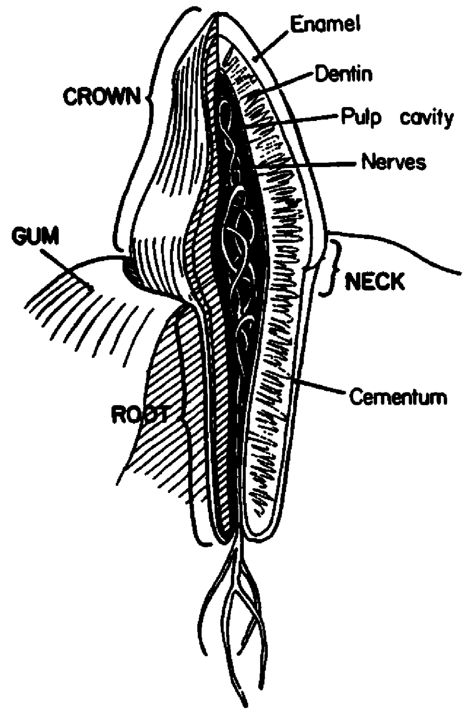

Figure 1: Cross section of a canine tooth (adapted from Shipman et. al, 1985)

The minerals comprising the outer layer are referred to as "enamel prisms," consisting mainly of calcium and phosphorous, which are packed into dense hydroxiapitate crystals (Whitney & Rolfes, 1996). A tissue itself is more readily preserved as its mineral content increases. With a tooth being over 90% mineralized, it tends to resist chemical and physical degradation better then other biologic entities (Wolpoff, 1996). This is ideal, since a tooth does not remodel, whereas bone possesses the ability. Overall, these factors create intrinsic characteristics unique to teeth, since they often "represent an unsurpassed record of the individual" (Alt, 1995: 262).

The progressive perfection of the human dentition has created quite a distinct anatomical structure. A human is classified as a heterodont and a diophyodont. A heterodont has more than one tooth type and a diophyodont produces only two sets of teeth in a lifetime. Besides these characteristics, a standard sequence of dental formation and eruption occur for both sets of teeth. Human dental development is thus represented by varied time periods. Within these time periods occur brief durations and narrow distributions, which tend to be more informative than those with long durations and wide distributions (Hagg & Tarranger, 1985). Overall, these unique characteristics aid in conducting research involved with human dentition. Quite often these dental attributes contribute to the inferences drawn upon for determining biological standpoints such as: age, sex, health, or diet (White, 1991). Dental research can be geared towards a population overview, detailing the use of a sample (which helps to interpret larger scales such as epidemiological perspectives or sociocultural practices), or the research may concern a case specific review, as can occur within a forensic science setting.

Thesis Focus

The purpose of my study is to evaluate (1) if adult tooth loss in humans is age-related, and (2) if this is found to be true -- how patterns of tooth loss relate to an estimate of age at death. One proportion I cannot identify is the sequence of tooth loss. However, if there proves to be an identifiable relationship between PMTL and age, then paleodemographic and forensic investigators will have a useful tool. Accordingly, in assessing patterns of frequency concerning PMTL, there may be a concomitant strategy in estimating age at death.

The Dental Research Focus

Dental research has traditionally focused on three areas:

1) Developmental changes encountered during growth phases such as mineralization, calcification and eruption processes (Schultz, 1934; Steggerda & Hill, 1942; Gustafson and Koch, 1974; Dahlberg, 1991).

2) Quantified dental biology in relation to age progression/age estimation and/or attrition rates (Gustfason, 1950; Burns and Maples, 1976; Smith, 1983,1984; Papapanou et al., 1989; Solheim, 1993; Vystrchova and Novotny, 2000).

3) Periodontal disease and its effect on oral anatomy (Clarke et al, 1986; Hildebolt and Molnar: 1991).

Rosing and Kvaal (1998), summarize an evaluation of methods applied to age estimation. These methods include research on the following variable(s): number of teeth, tooth color, fluorescence, attrition, crown height, periodontal recession, cementum apposition, root resorption, secondary dentin, pulp chamber width, pulp chamber area, pulp chamber weight/height index, dentin thickness, root translucency, peritubular dentin, racemisation, cementum annulation and a variety of combinations of these variables.

Periodontal disease, which encompasses issues of oral pathology, is a major contributor to the predisposing factors involved with tooth loss. Periodontal disease, as stated by Hildebolt and Molnar (1991:225), encompasses

"the intermittent degeneration of the supporting tissues of the teeth, these tissues being the gingiva, cementum, periodontal ligament and alveolar bone. The ultimate sequela of this process is the wasting of the periodontal structures to the point that teeth are lost due to inadequate surface attachment for ligaments because of reduction of bony support".

Twentieth century investigations abound in useful reports detailing oral anatomy. The last century and beyond has produced several useful skeletal/dental criteria from scholars such as: Brekhus, 1928; Hellman, 1936; Gustafson, 1950; Garn et al., 1958; Szabo, 1959; Brothwell et al., 1963; Clement, 1963; Bang and Ramm, 1970; Johanson, 1971; Ito, 1971; Demirjian et al., 1973; Burns and Maples, 1976; Levesque et al., 1981; Hagg and Taranger, 1985; Smith, 1987; Papapanou et al., 1989; Solheim, 1990,1992,1993; Harris and Rathbun, 1991; Hartnady and Rose, 1991; Larsen et al., 1991; May et al., 1995; Russell, 1996; Shugars et al., 2000;Vystrchova and Novotny, 2000; Solari and Abramovitch, 2002. These studies illuminate an array of tendencies fashioned by human dentition. The substantial amount of knowledge generated and its relevance to biological anthropology is considerably valuable. Overall, studies yield a corollary suggesting that teeth encounter variations due to ecological, biological, physical and sociocultural influences. This interaction occurs in such a way that phenotypic effects displayed by teeth have a tendency to fluctuate. Dahlberg (1964) explains that even though teeth are sturdy there are new and unanticipated problems accompanying present day circumstances. In large, civilization subjects itself to varying circumstances and thus tooth research continues to appoint arising situations.

The following list contains specific tooth studies, which exemplify the theme discussed above:

1. Subsistence patterns and the ecology of the exploited land areas of peoples has demonstrated that tooth wear varies (Smith, 1983, 1984; Hartnady & Rose, 1991).

2. In relation to dentition, the concepts of sex and race continue to be researched (Brekhus, 1928; Hellman, 1936; U.S. Dept. of Health, 1960-62; Garn et al., 1958, 1972; Steggerda and Hill, 1942; Johanson, 1971;Levesque et al., 1981; Hagg and Taranger, 1985; Smith, 1987; Larsen et al., 1991; Solari & Abramovitch, 2002).

3. Sociocultural practices of intervention through dentistry, i.e., public dental clinic versus private clinic practice, has accompanied efforts of assessing age from particular tooth values (Gustafson, 1950).

4. The physical component of bone mineral density has been researched in relation with its relevance to tooth loss (May et al., 1995).

5. Studies have expanded to cover demographics and investigate post-reproductive individuals, residence and tooth loss (U.S. Government Printing Office, 1999).

6. Research has been conducted on a group of postmenopausal women. Data gathered on these women regards particular interaction between tobacco

smoking and personal tooth loss (Daniell, 1983).

PMTL Study and Its Course of Research

Although the dental research agenda has been dominated by methods prescribing to alternative techniques, the focus of this study reviews tooth loss. It seeks to explicate the value that the presence or absence of teeth displays or a value that coincides with the presence or absence of teeth within partitioned dental arches. A limitation of current adult age-estimation techniques is that they do not sample the post-reproductive years of life (i.e., 50-100) very well. Yet the major demographic trend in the 20th century was decreased mortality and increased survivorship, where human populations now contain growing numbers of post-reproductive individuals. As posited by Freeman (1960: 20),

"The factors involved in geratologic expressions are a rising population, a stable or rising birth rate, a falling death rate, and a transition from the immediate effects of acute diseases to the delayed summated effects of degenerative diseases".

Currently this trend seems to be continuing. Perhaps results of this study may establish extended ranges of dental age estimation inclusive of the young adults, those classified as middle-aged and post-reproductive individuals. Formal standards may be able to extend themselves more broadly as criteria to be used within the disciplines of paleodemography, historic anthropology and forensic science.

Thesis Outline

This thesis is divided into six chapters, the first of these being this Introduction. Chapter 2 outlines the sample of human skeletal material assayed for use within this research, while it also includes a description of the methodology used for data collection and the statistical analysis executed. Results generated from data review and subsequent statistical computations are discussed in chapter 3. Chapter 4 encompasses the interpretation of these results. Chapter 5 details the conclusions of this endeavor as applied to the theoretical implications of biological anthropology.

Chapter 2: Materials and Methods

Human Skeletal Collection: Sample of Black Females

This investigation reviews a skeletal sample that is sex and "race"* specific. The individuals represent life histories of the late 1800s through the mid 1900s. Materials of the study consist of black females from the Hamann-Todd Skeletal Collection permanently housed at the Cleveland Museum of Natural History. These individuals were principally subsiding in the Cleveland, Ohio area prior to death. Cadavers were received from local medical institutions during the span of 1911 through 1931. Their reception occurred at the Western Reserve Anatomical Laboratory where a routine procedure was executed (Cobb, 1932).

The sample includes 237 dentitions that were macroscopically examined for acquired dental pathologies. The pathologies assessed are as follows: premortem tooth loss (PMTL), necrotic crowns, peri-apical abscesses, root fragments, caries, developmental anomalies and dentistry. Sample individuals range from 18 –89 years of age. Only those individuals with complete maxillary and mandibular jaws were considered within the study. Individuals with amalgams (dental fillings) were included within the sample, while those with advanced dentistry (i.e., bridge work, crowns, dentures etc.) were excluded. This information was recorded using a data sheet, which

* The term "race" is not a biological entity when used within this thesis, but rather it is perceived as a social construct that references ethnic identity.

partitioned observations for each tooth with respect to location (i.e., maxillary, mandibular, left, right). Refer to **Table 1**. Upon completion of data collection the information was transferred to an electronic database for permanent storage and statistical analysis (HP Pavilion 8485Z and SPSS 10.0 Windows software).

HT Specimen No. ____________

Age: ____________

Sex: ____________

Race: ____________

MAXILLA	RAB																	
	RF																	
	NC																	
	PTL																	
	Ⓛ	M3	M2	M1	P4	P3	C	I2	I1	I1	I2	C	P3	P4	M1	M2	M3	Ⓡ
	Ⓛ	M3	M2	M1	P4	P3	C	I2	I1	I1	I2	C	P3	P4	M1	M2	M3	Ⓡ
MANDIBLE	PTL																	
	NC																	
	RF																	
	RAB																	

PTL: Premortem Tooth Loss
NC: Necrotic Tooth Crown
RF: Root Fragment(s) (+/-)
RAB: Root Abcess (+/-)

Table 1: Data Collection Sheet

<u>Scoring Methodology: Distinguishing Premortem and Postmortem Loss</u>

Data were collected using a binary system of relation. Scoring methodology reviewed the presence or absence of each tooth within its respective alveolus. Tooth absence, as being a premortem phenomena, was determined if a tooth socket displayed bone resorption. Areas involved with resorption were distinguished by evidence of osteoclast activity, osteoclasts being bone-destroying cells. In areas of the dental arcades where this type of activity was evident the assessment was scored as absent. Absence in this case equates to PMTL.

The following is a brief explanation of bone resorption. Sicher and DuBrul (1975:261), have posited that while teeth encounter stages of growth, a summary of the movements of teeth can be classified as follows:

> "Preeruptive movements
> Eruptive movements
> Prefunctional period
> Functional period"

The important concept here is the existence of a tooth within the jaw matrix during life and its movements. This activity lends itself to their additional explanation regarding bone resorption:

> "The rapid release of the minimal pressure caused by the proliferation of osteogenic tissue is, in all probability, the reason for an orderly pattern of bone resorption. Growing and cell-covered areas of bone and cementum are thus "protected" (Sicher & DuBrul, 1975:278).

The use of "protected" here suggests that bone resorption would most likely not induce its activity on an area of bone that displays functional movement, i.e., functional movement of a tooth during life. Thus if PMTL occurs, a macroscopic observation is possible, considering the observer has a conceptual understanding of the reaction of bone to pressure and the modeling of resorption.

In the case of the absence of a tooth within a particular alveolus, where the socket displayed a "clean-smooth" appearance, the observation was assessed as present. The "clean-smooth" appearance of the bone suggests that a functional tooth inhabited the socket prior to death and bone resorption was never initiated. For these cases, it was deduced that tooth loss was a postmortem occurrence, perhaps due to the decomposition of Sharpey's fibers or external trauma.

Additional Assessment Criteria

Macroscopic assessment performed in this study could not account for unerupted teeth, as no radiographs were reviewed. If indeed a tooth was unerupted, it was scored as absent.

Third molars were scored in the same manner designated for all other teeth. In particular, this tooth has a tendency to display higher proportions of congenital absence (Levesque et al., 1981). Studies suggest that the distribution of molar three agenesis varies according to factors of sex and "race" (Hellman, 1936; Garn & Lewis, 1962; Levesque et al., 1981) and geographical evolutionary reduction (Brace, 1991). Although this information has been posited, these teeth are included in the statistical procedures used here.

Statistical Procedures Used For Data Analysis

Checking the Assumptions

Data were examined in a multivariate context. This was accomplished by assessing the fit of the sample in relation to the assumptions underlying a regression variate. In this case, the dependent variable (DV) is the only metric variable and it refers to age at death of sample individuals. This variable is positively skewed, as several individuals represent the mid to lower age range. Therefore the assessment of age at death in this form does not display normality. Individuals who represent moderate to marked post-reproductive ages are underrepresented (i.e., ages 45+). In conducting a LG_{10} transformation, which produces the effect of reflect and logarithm, a fairly normally distributed DV is revealed. Even so, the study continued with the use of the dependent variable with no transformation performed upon it. This was done since with reasonably large samples "a variable with statistically significant skewness often does not deviate enough from normality to make a substantive difference in the analysis" (Tabachnick & Fidell, 1996: 73).

Varimax Factor Analysis (VFA)

This procedure allows for all the independent variables (IVs) to be reviewed simultaneously. IVs of this study are in the form of nominal data and represent the 32 permanent teeth of the two dental arcades. On account of their multitude, select measures were taken to create indices comprised of only those variables with high and unitary loading on a given factor. IVs were processed as such, in order to create more stable and reliable indicators in subsequent analysis.

Following the initial run, the rotated component matrix was analyzed. Where there were significant correlations between teeth, interrelationships between variables indicated interdependence between them. In particular, the Varimax rotational method was chosen because it allows for orthogonal selection of factors. The use of VFA assisted in comprehending the emerging "factors" inherent to the data. It also served as an aid in deciphering underlying dimensions of the study through data reduction.

Overall eleven consecutive VFA runs were produced. For each run the communality scores were reviewed. Communalities refer to the amount of variance a variable shares with all other variables (Hair et al., 1998). If a particular variable exhibited a communality that was low (below .300) in comparison with others in its associated factor, then it was deleted from the variable pool prior to the next run. If the rotated component matrix of a run did not produce a communality score within this range, the next criteria considered was factor loadings. Factor loadings exhibit the correlation between each variable and the factor in which it loads (Hair et al., 1998). Any variable with multiple loadings across factors was deleted. The effect of "double loading" can obscure interpretation of dimensions and facilitating such an initiative avoids this tendency.

Respecification of the model continued until factors were unidimensional. This refers to the assumption that the variables within each factor are strongly associated with one another and represent a single concept, where then it is appropriate to create a summated scale (Hair et al., 1998). This standing was achieved once the high load for each remaining item occurred only on one factor.

Reliability Test

Ultimately the data produced five emerging factors. Since there was a desire to scale these factors, it seemed appropriate to measure their internal consistency. Cronbach's alpha or coefficient alpha was the model designated for the alpha factor extraction. With this model, greater internal consistency occurs as the measure of alpha approaches 1.00 (George & Mallery, 2001).

In reviewing coefficient alpha scores, it was evident that no benefit would transpire if factor items were deleted. In addition, items were not converted to standardized form since all standardized alpha scores proved to be within near proximity to the coefficient alpha scores. Although all factors did not prove to be absolutely additive, the internal reliability of each set of correlated variables did provide acceptable alpha levels for facilitating the creation of indices.

Post-Hoc Methods: Multiple Comparison Test

A one-way ANOVA was run for each of the indices. The Tukey HSD test was selected on account of the many levels contained within the indices (George & Mallery, 2001). Levels in this case correspond to the number of teeth exhibiting PMTL within an index. These levels are displayed in association with their representative mean at age death. A score of 0 (zero) here equates to all of the teeth being lost within a particular index, while ascending numbers represent the presence of additional teeth.

The Levene statistic, testing homogeneity of variance along with the F-statistic, significance value (Sig.) and the effect size (eta squared) were reviewed. No violation was assumed to have occurred if the Levene test produced a significance value greater than 0.05. If the Sig. Value, from within the ANOVA table, exhibited a value less than or equal to 0.05, then a difference was assumed to have occurred among the mean scores on the DV for the groups (Pallant, 2001). Effect size was reviewed by calculating eta squared. The strength of association is reviewed here, as to "assess the amount of total variance in the DV that is predictable from knowledge of the levels of the IV" (Tabachnick & Fidell, 1996: 53). Effect size is classified as follows: .01 equates to a small effect, .06 equates to a medium effect and .14 equates to a large effect (Cohen, 1988).

In compliance with satisfied significance levels, post-hoc tests of homogeneous subgroupings were considered in regrouping levels within these five indices. Use of this method led to an alternative combination of items. Ultimately, indices were renamed following this procedure. They were also recoded according to empirically based scaled values. Of the five indices only one reduced to a dummy variable. Overall, the review of these homogenous subsets established an empirical basis for the assignment of numeric value to these indices. This procedure also facilitated scale constructions that would satisfy a linear model.

Stepwise Regression

Five scaled indices and three alternatively coded indices and the DV were analyzed with this procedure. The sequential approach of stepwise estimation allowed for the elimination of IVs. This could occur if an IV entering the recomputed regression equation altered the others previous significance (Hair et al., 1998).

Following this run, the five original indices were selected as variables of choice and were analyzed one final time. The correlation matrix was reviewed for multicollinearity, while the DV was regressed on each IV. From the model summary, which reflected three emerging variables, R^2 and Adjusted R^2 were evaluated. Finally estimates pertaining to these predictor variables were assessed via the coefficient matrix.

Chapter 3: Results

Descriptive Statistics

The Dependent Variable

This study represents an investigation of skeletal biology in relation to the process of aging. Its 237 sample individuals vary across a range representative of eight decades. For interpretation purposes, age was partitioned into three groups. The groups are based on broad phases concerning biological maturation processes. The following information details the partitioned age ranges and their associated phase:

Ages 18-39 = the young (active growth phases, reproductive years of life)

Ages 40-59 = the middle aged (degenerative phases transpire)

Ages 60+ = the post-reproductive (continuation of degenerative phases)

Refer to **Table 2** for the sample frequencies within these ranges.

(%) of Partioned Ages for the Young, Middle Aged, Post Reproductive
HT Balck Females

	Frequency	Percent	Valid Percent	Cumulative Percent
age 18-39	127	53.6	53.6	53.6
age 40-59	75	31.6	31.6	85.2
age 60+	35	14.8	14.8	100.0
Total	237	100.0	100.0	

Table 2: Partitioned Sample Age at Death - Frequency (%)

The Independent Variables

Frequency data concerning the thirty-two IVs, representing each tooth of the permanent dentition, are best displayed by quadrant. Two arcades comprise the oral dental structure. The top jaw of this structure is referred to as the maxilla and the bottom the mandible. For both jaws an imaginary line of symmetry occurs between the midline of the front incisor teeth. With this in mind, each arcade then contains two halves, a bilateral left and right side. These divisions result in a structure referred to as a dental arch. Thus two dental arches comprise each arcade, resulting in a total of four arches. These arches are best thought of as segments that reflect a particular position within the structure.

Under normal eruptive circumstances all arches contain the same pattern of teeth. Tooth types within an arch are 2 incisors, 1 canine, 2 premolars and 3 molars, anterior to posterior in orientation respectively. Refer to **Figure 2** for a visual representation of two dental arches and the abbreviations accompanying each tooth. Bar charts, SPSS output and thesis text also contain additional shorthand preceding these abbreviations. The following shorthand is used within the text – Lman, Rman, Lmax and Rmax, which refer to left (L) or right (R) and mandible (man) or maxillary (max) orientation.

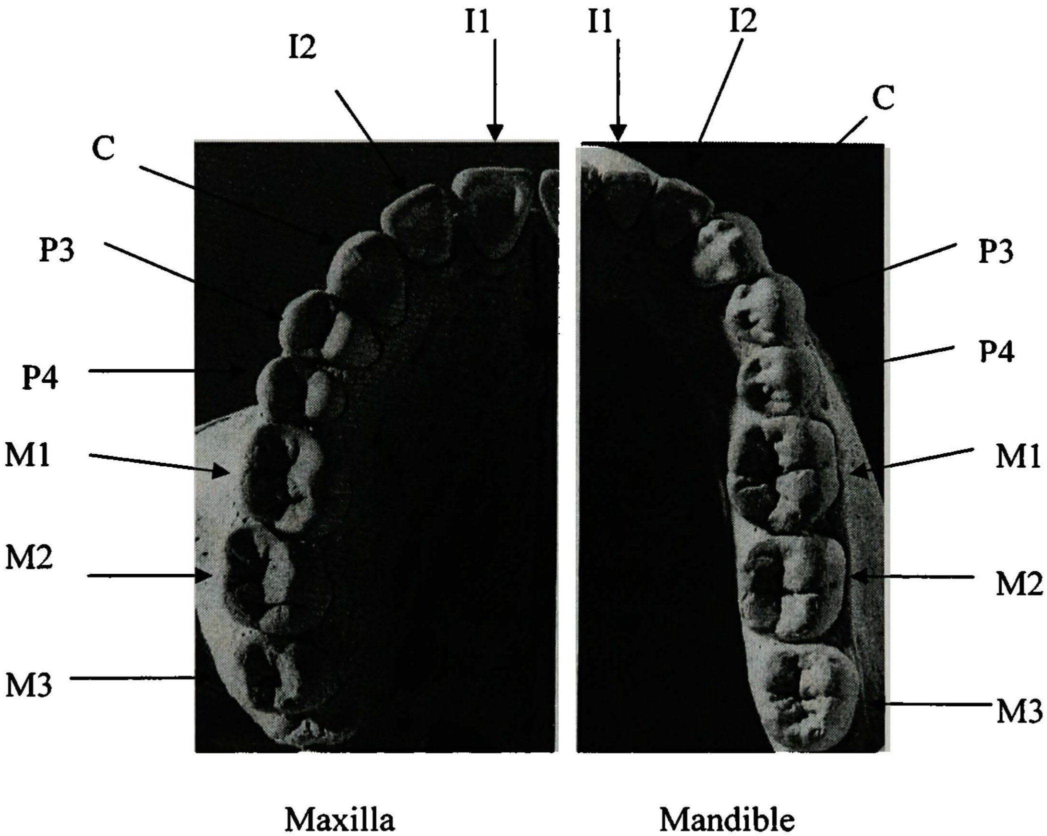

Figure 2: Maxillary and Mandibular Arches (adapted from White, 1991)

Frequency Data of PMTL (%)

Sample Distribution of Amalgams (%)

Prior to reviewing tooth loss percentages across the jaws, an overview of dental intervention is addressed. The focus is on the presence of amalgam(s). At the time of data collection each tooth was scored as to whether it exhibited evidence of an amalgam. For the frequency of overall occurrence across sample individuals refer to **Table 3**.

(%) of Dental Intervention Via Amalgam(s) Across All Ages: HT Black Females

	Frequency	Percent	Valid Percent	Cumulative Percent
evidence of fillings	18	7.6	7.6	7.6
no evidence of fillings	219	92.4	92.4	100.0
Total	237	100.0	100.0	

Table 3: Frequency of Individuals with Amalgam(s)- Dental Fillings

The presence of amalgams occurs across all decades of the sample up through age fifty-one. After this age, sample individuals lack the presence of amalgams. Although this is not to say that these individuals or any others lacking the display of the treatment had never had an amalgam, as a lost tooth itself may have exhibited this characteristic. Overall, sample individuals exhibit a low proportion of this type of intervention.

PMTL Across the Maxillary and Mandibular Arches (%)

Refer to **Figures 3a, 3b, 3c and 3d** in regard to PMTL percentages across the entire age range of the sample. These figures depict the left/right maxillary and left/right mandibular arches respectively.

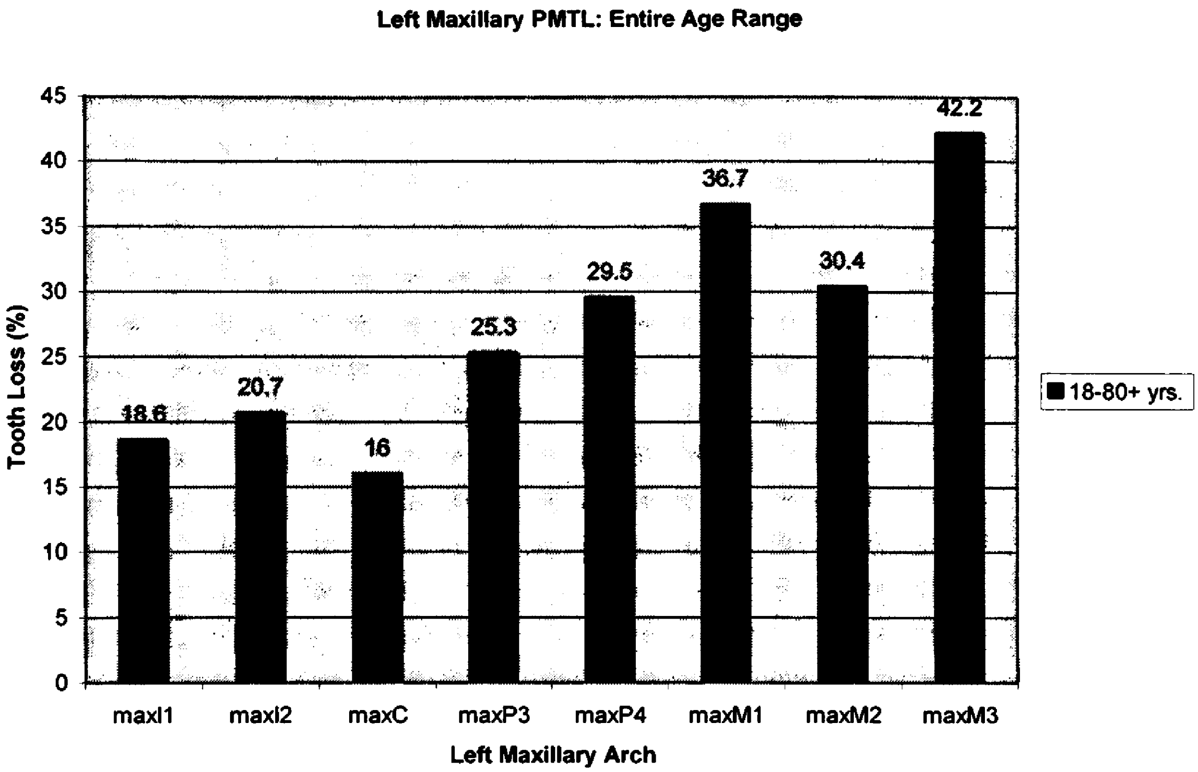

Figure 3a: Left Maxillary PMTL: Entire Age Range Frequency (%)

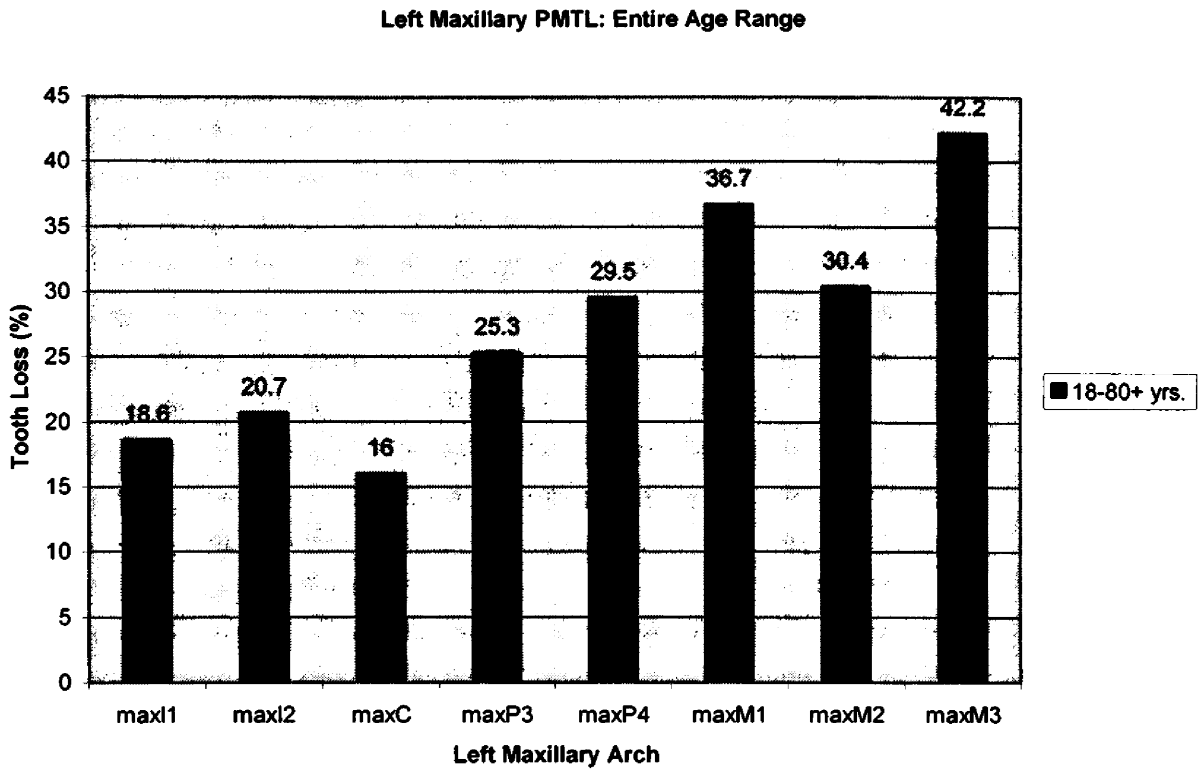

Figure 3a: Left Maxillary PMTL: Entire Age Range Frequency (%)

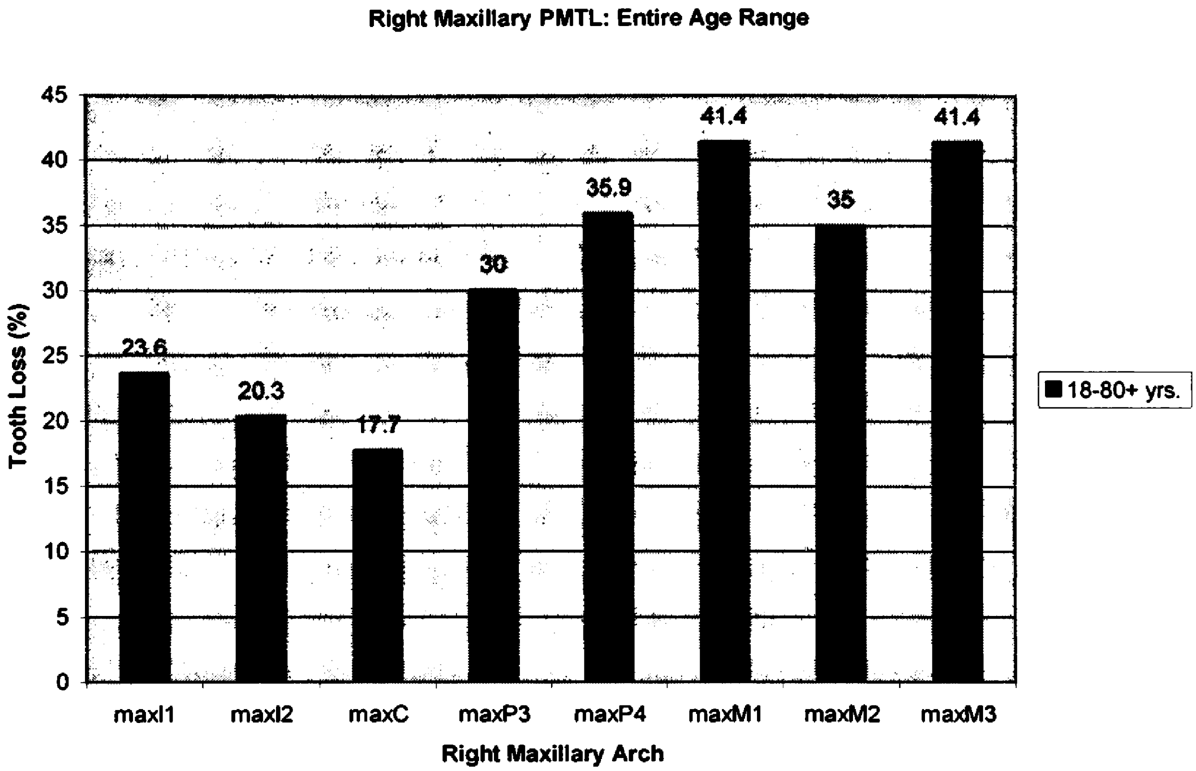

Figure 3b: Right Maxillary PMTL: Entire Age Range Frequency (%)

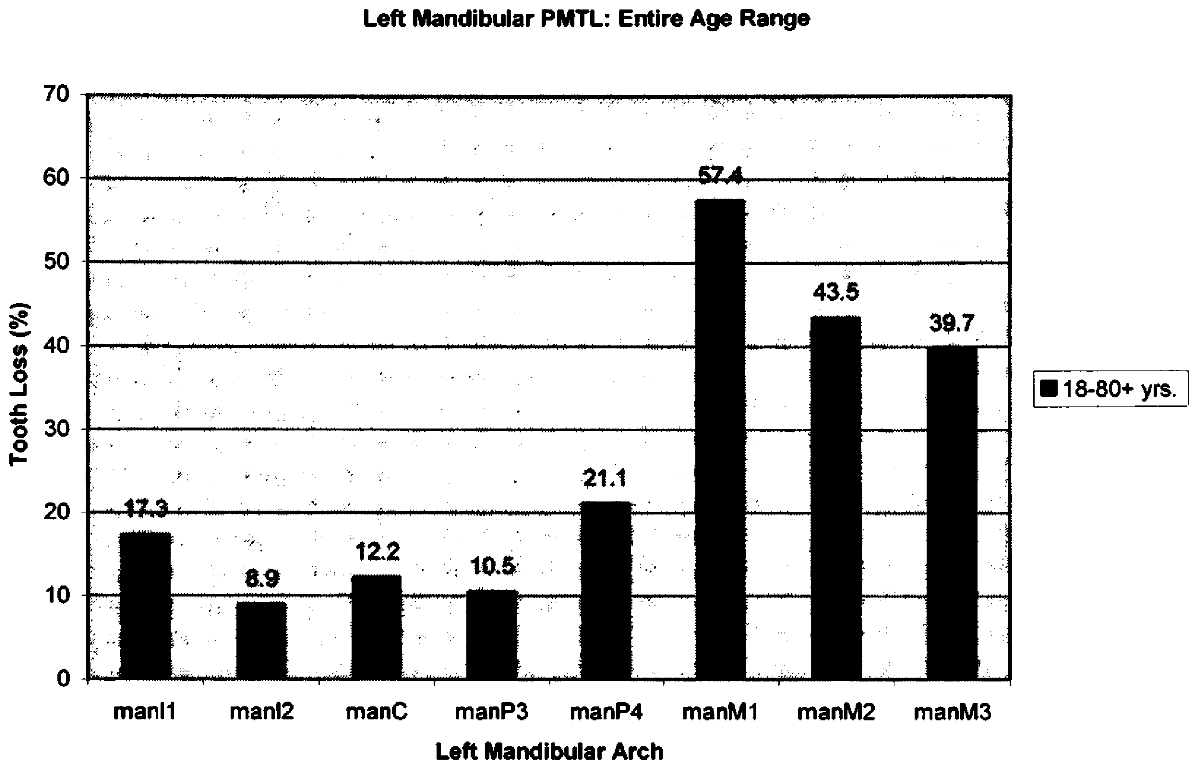

Figure 3c: Left Mandibular PMTL: Entire Age Range Frequency (%)

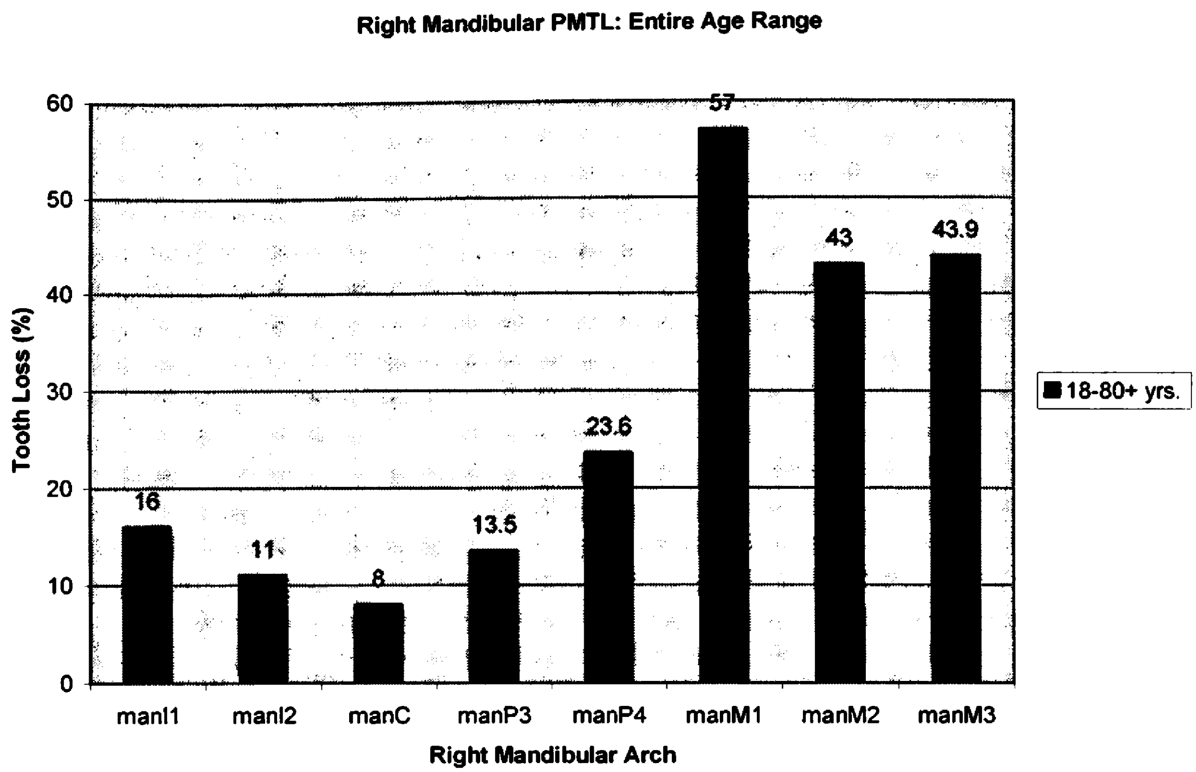

Figure 3d: Right Mandibular PMTL: Entire Age Range Frequency (%)

Mandibular M1's exhibit the highest percentage of PMTL across the sample. The left and right arches of the mandible display 57.4% and 57% loss for this tooth respectively. The maxillary arches exhibit the highest percentage of PMTL for a particular tooth. This corresponds to the M3's, as left and right display 42.2% and 41.4 % respectively. Although, the RmaxM1 displays the exact same PMTL percentage as does its M3. Overall this sample reveals increased PMTL across molar teeth in comparison to others, particularly M1's and M3's.

Canines exhibit the least amount of PMTL across all arches. Maxillary anterior teeth exhibit higher overall PMTL in comparison to the same mandibular teeth. In particular, the I2 of the left/right occlusal anterior teeth display a considerable fluctuation in loss percentage. The occlusal plane occurs at the junction of the maxillary and mandibular teeth. For instance, LmaxI2 experiences 20.7% PMTL while the LmanI2 holds at 8.9%. The same PMTL fluctuation occurs for the right anterior occlusal plane, as the RmaxI2 displays 20.3% PMTL in comparison to the RmanI2 showing 11%. PMTL across this sample is more variable between teeth that occlude, as they generally exhibit quite different percentages of loss.

Comparing Bilateral Arches

Considering the maxillary and mandibular arcades, there is less fluctuation of PMTL when comparing each of their bilateral arches. This refers to the comparison of the same teeth from each side of a specific jaw. Loss percentages are displayed in the following tooth order: left/right anterior (I1, I2, C) and left/right posterior (M1, M2, M3) segments.

Each of the two arcades displays similar percentages of PMTL for these segments. For example, the left mandibular anterior segment exhibits 17.3%, 8.9% and 12.2% loss, while its right anterior segment exhibits 16%, 11% and 8% loss respectively. These same maxillary segments also exhibit similar loss percentages when compared to one another. The left maxillary posterior segment exhibits 36.7%, 30.4% and 42.2% loss, while the right posterior segment exhibits 41.4%, 35% and 41.4% loss. These same mandibular segments also exhibit similar loss percentages when compared to one another; in fact they are even closer in range. Overall, the anterior segments of both jaws exhibit lower percentages of PMTL loss in comparison to posterior segments, while each of the bilateral segments tend to exhibit similar PMTL percentages.

PMTL for Partitioned Age Ranges (%)

Data figures are also available for PMTL percentages in accordance to partitioned age ranges. Refer to **Appendix A1, A2, A3 and A4**. An overview of the bracketed age data provides general detail concerning sequence of loss, although the exact time of loss for any tooth in this sample is unknown. The youngest group can be viewed as a focal point from which teeth were lost prior to the degenerative phases of the life cycle. For example, the mandibular molars display higher percentages of PMTL within the 18-39 year old age group in comparison to other teeth. In particular, the left and right M1's already approach 50% loss.

Varimax Factor Analysis

The thirty-two items of the PMTL study were analyzed with the principal components analysis (PCA) using SPSS. Prior to performing the PCA the suitability of data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of many coefficients of .3 and above. The Kaiser-Meyer-Oklin value was .900, exceeding the recommended value of .6 (Kasier, 1970, 1974) and the Bartlett's Test of Sphericity (Bartlett, 1954) reached statistical significance, supporting the factorability of the correlation matrix.

PCA revealed the presence of seven components with eigenvalues exceeding 1, explaining 35.9%, 6.8%, 5.5%, 5.4%, 4.4%, 3.7% and 3.1% of the variance respectively. These seven factor solutions explain 64.7% cumulatively for variance. To aid in the interpretation of these seven components, Varimax rotation was performed. The rotated solution revealed seven components with only five of them showing a number of high loadings. Refer to **Table 4.** Refer to **Appendix B** for the unrotated component matrix.

Rotated Component Matrix [a]

	Component						
	1	2	3	4	5	6	7
right max I2	.820						
right max I1	.749						
left max I1	.746						
left max I2	.651		.366				
left max C	.642		.331				
right max C	.641						
right man I1		.833					
left man I1		.809					
right manI2		.770					
left man I2		.743					
right max P4			.718				
left max P4			.715				
left max P3			.666				
right max P3	.338		.612				
left max M1		.303	.608				
right max M1			.484	.324			.329
left max M2		.306	.441	.409			
right man M3				.680			
right max M3				.672			
left man M3				.643			
left max M3			.343	.622			
right max M2			.305	.596			
left man M2				.479		.408	
right man P4					.760		
right man P3		.375			.538		
right man M2				.417	.519	.301	-.317
right man C		.466			.505		.309
left man P4	.352		.307		.486		
left man P3		.485			.486		
left man M1						.859	
right man M1						.833	
left man C							.747

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 8 iterations.

Note: Only loadings above .3 are displayed.

Table 4: Varimax Rotated Component Matrix of the Initial Run / Hamann-Todd PMTL Items

This matrix reveals double loading across several of the variables within the components. On account of this, consecutive VFA runs were conducted. A desirable result was achieved after the eleventh run. A review of communality scores and double loading followed each run. **Table 5** below details the criteria upon which deletion of a variable was based. An "X" within the "low communality" column or the "double loading" column indicates that this criteria supported variable deletion prior to the next run.

VFA Run	Low Communality Score	Double Loading	Variable Dropped
Initial		X	LmanP3
1		X	RmaxM1
2		X	LmaxM2
3		X	RmanC
4		X	LmanP4
5		X	RmanM2
6		X	LmanM2
7		X	LmanC
8		X	RmanP3
9	X		RmanP4
10	N/A	N/A	N/A

Table 5: VFA- Criteria Used for Variable Deletion

The seven components reduced to six components following the first run. Upon the ninth run the matrix reduced to five components. This run produced a low communality score of .273 that corresponded to RmanP4, while double loading was not a problem. In accordance to this score, this item was last to be deleted prior to the final run.

Ultimately, data reduction produced five components that support the use of the items as separate scales. They cumulatively explain 66.7% of the variance. Fortunately, the items within each component produce factors that have a common theme as they represent divergent groups, when considering their position in the jaw or tooth type. Refer to **Table 6** for the final rotated VFA matrix.

The following list concerns theoretical themes underlying the factors:

Factor 1: depicts maxillary anterior teeth (R/L I1, I2 and C).

Factor 2: depicts maxillary mid-posterior teeth (L/R P3, P4 and L M1).

Factor 3: depicts mandibular anterior teeth (L/R I1 and I2).

Factor 4: depicts molar teeth (All M3's and right maxillary M2)

Factor 5: depicts L/R mandibular M1's (six year molars).

Since the items within these indices were produced by the data reduction procedure, they were named Fac1, Fac2, Fac3, Fac4, and Fac5.

Rotated Component Matrix [a]

	Component				
	1	2	3	4	5
right max I2	.834				
left max I1	.758				
right max I1	.750				
right max C	.677				
left max C	.663	.366			
left max I2	.653	.328			
left max P4		.776			
right max P4		.768			
left max P3		.678			
right max P3	.336	.648			
left max M1		.559			
right man I1			.835		
right manI2			.820		
left man I1			.807		
left man I2			.803		
right max M3				.721	
right man M3				.687	
left max M3				.677	
left man M3				.667	
right max M2				.613	
left man M1					.880
right man M1					.863

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

Table 6: Rotated Component Matrix- Final VFA Run

Refer to **Appendix C** for the unrotated matrix of the final VFA run.

Reliability Test

Additional restrictions were placed upon the five indices of this study. Prior to advancing with subsequent procedures a reliability test was conducted. The intention of this test is to assess the internal consistency of each index. Particularly, the Cronbach's alpha score was checked, as a means to review which items should be kept within the indices. Furthermore, the test helped to determine the appropriateness of creating summated scales with these items.

The Alpha value of each index along with its standardized item alpha score is reported in **Table 7** below:

Index	Alpha value	Standardized item alpha
1	.8815	.8818
2	.8298	.8309
3	.8979	.9010
4	.8052	.8050
5	.8343	.8343

Table 7: Reliability Test- Alpha values and Standardized item alpha scores

Standardized scores were not considered for use, since they display values within near proximity to Alpha values. In addition, no items were deleted because Alpha scores would not have improved.

All Alpha values exceed .7, which is considered to be an "acceptable" level. In fact, values exceed ratings of "good" depicted by Alpha values above .8 (George & Mallery, 2001). The "corrected item-total correlation" calculations are also of interest.

These figures lend themselves to the "indication of the degree to which each item correlates with the total score", where "low values (less than .3) here indicate that the item is measuring something different to the scale as a whole" (Pallant, 2001: 87). All items fared well in this case, as the lowest "corrected item-total correlation" calculation produced was .5118. These tests suggest that the variables are reliable and that they provide an internal consistency suitable for use within summated scales.

Post-Hoc Methods: Multiple Comparison Test

A one-way between-groups analysis of variance was conducted to explore the impact of PMTL on levels of age. Subjects were divided into groups according to PMTL incidence within each index. Since no gross violations resulted from the multiple comparison tests, the homogeneous subsets were regrouped. Following this, scales were created through recoding the data program and each index received a new variable name. The scale values associated with this recoding process represent the actual number(s), which correspond to the predictor variable(s) used to compute the regression equations. Below are the new variable names.

Fac1 index = HOCGP1A
Fac2 index = HOCGP2A
Fac3 index = HOCGP3A
Fac4 index = HOCGP4A
Fac5 index = HOCGP5A

A detailed review of HOCGP1A index is provided in the following paragraph. To review such detail for the other factor indices refer to **Appendix D**.

not violate the assumption of multicollinearity (equal to or above .7) amongst themselves (Pallant, 2001). While this model will be discussed at this point, note that two additional models emerged from this procedure. They are reviewed within the next chapter in regard to their value when considering differential preservation of skeletal material.

Table 8 displays the correlations between variables, the standardized regression coefficients (Beta), along with R^2 and Adjusted R^2. In addition, the total explained variance of the IVs is included. This measure is calculated by multiplying each Beta coefficient by its respective correlation coefficient. These figures, which are adjusted partial slopes called beta weights, "indicate how much change in the dependent variable is produced by a standardized change in one of the independent variables when the others are controlled" (Blalock, 1960:345). Only three of the IVs contributed significantly to prediction of age at death. Altogether, 39% (38% adjusted) of the variability in age at death was predicted by knowing the scores of tooth absence/presence within these three indices.

Table 8: Stepwise Regression of Human Tooth Segments on Age at Death

Variables	Age (DV)	HOCGP2A	HOCGP4A	HOCGP3A	B	β
HOCGP2A	-.5518				-6.8663*	-.3255
HOCGP4A	-.5354	.5482			-4.2547*	-.3063
HOCGP3A	-.4069	.4838	.4204		-2.8282*	-.1207
				Intercept=	62.8057	
Means	40.9789	1.4684	1.6329	1.6962		
Standard Error of Est.	11.8483					R^2=.39
						Adjusted R^2=.38
						R =.63

*p≤ 0.05

Total Explained Variance	
HOCGP2A =	.1796
HOCGP4A =	.1640
HOCGP3A=	.0491

This model satisfies the following equation:

Y= 62.8 - 6.9(HOCGP2A) - 4.3(HOCGP4A) - 2.8(HOCGP3A)

Standard Error of Estimates +/- 11.8483

Refer to **Appendix E** for the Model Summary, ANOVA and Coefficients output corresponding to the above Stepwise Regression overview.

Chapter 4: Discussion

Valuable Criteria: Tooth Loss and Its Associated Stages

There does seem to be a value in assessing PMTL and age estimation. Attrition, which contributes to tooth loss as it nears the terminal stage, most likely exhibited a strong influence on this sample. The actual wearing of teeth against one another results in attrition (Dahlberg, 1960). The process is slow and begins as the permanent dentition approaches completion. At later times attrition accentuates, while criteria such as functional wear and biological degenerative phases transpire.

Functional wear can be either at the occlusal and/or interstitial plane of teeth (Steele & Bramblett, 1988). The occlusal plane occurs where the opposing teeth of the jaws meet, while the interstitial plane occurs between two adjacent teeth. Biological degenerative phases include criteria such as, exposure of the pulp chamber, bacteria invasion, caries, abscesses and the death of a tooth. Ultimately a tooth will exfoliate and the remaining teeth generally become involved with mesial drift or other alterations deviating from the normal dental arch display.

This sample most likely exhibited an interaction with the degenerative phases associated with teeth. While some of the dentition contained healthy teeth, several more in comparison lacked this condition. The fact that this sample exhibited minimal dental intervention initiates an additional inquiry. This inquiry concerns disease processes inherent to this sample. For instance, it was not until after the first few decades of the nineteenth century that bacterial diseases had medicinal counteractions. Remedies were not available until the advent of antibiotic agents revolutionized through the discipline of microbiology in the 1930s. Remedies were later purified in useful form in the 1940s (Jensen et al., 1997). Given that these individuals encountered life prior to this revelation, the fatality of disease would have rendered its destructive path on those afflicted. Thus it would be interesting to review chronic versus acute disease in light of the possibility of facilitating accelerated tooth loss. This could be accomplished by reviewing an additional treatment, such as cause of death across the sample. This type of assessment could be sought because approximately 95% of the entire skeletal collection has the sex, race, age, cause of death (COD), date or receipt and source in the city documented (Cobb, 1932).

Theory and the Distinguishing Attributes of Teeth

Under normal developmental circumstances teeth follow a standard sequence of formation and eruption. Tooth classification reflects both morphology and function of the respective tooth. Some teeth appear more stable and less variable than others (Bass, 1995). The incisors are chisel-shaped and aid in cutting, canines exhibit single cones and aid in tearing, premolars usually display two cusps and molars three cusps, while both aid in grinding (Chung, 1995).

Teeth are believed to have a genetic predisposition as they take on "specific purposes" in life. As from within Bass (1995:273), "Dahlberg feels that different tooth groups are under different morphogenetic fields and that these fields are concentrated as certain teeth within the tooth group." He claims that teeth are "orderly" in regard to variations and origins of their structures. He posits that these structures, i.e., cusp size and root systems to name a few, do propose "enough different degrees in expression and frequency of occurrence to distinguish one population from another" and in turn, "permit strong arguments in statistical probability and thus allow their use in identification of individuals" (Dahlberg, 1963).

In light of this explanation, it seems that this study adheres to the above concept. In particular, the study explicates an alternative focus. It reviews the component of tooth loss as to derive individual age assessment through the use of statistical inferences. Analytical review of the sample data supported an analysis that refuted the existence of equal means across the sample between its IVs and the DV. Furthermore, techniques were employed that sought to explore the structure and interdependence of the sample. The indices produced from this study were practical as their variable combinations coincided with theory. For instance, the indices grouped as concentrated fields of teeth, (i.e., as certain teeth within a segment), or by the type of morphology/function exhibited by the teeth. The fact that the emerging dimensions of this analysis are supported by a theoretical sense reduces the risk of finding results with little or no generalizability (Hair et al., 1998).

Consequently, the five emerging indices were analyzed for their ability to support a dependence model. In terms of these indices, an evaluation of the model was analyzed through a stepwise regression procedure. This procedure indicated that three of the five best correlated to age. In calculating the "total explained variance" of these three coefficients, two of them attributed most value, exhibiting 17.96% and 16.40% respectively. The third coefficient explained minimally, exhibiting 4.91%. Overall, through the assessment of the data in conjunction with a multiple regression analysis, the investigation satisfied a linear prediction model pertaining to age at death of an individual.

Differential Preservation of Skeletal Material: Two Additional Models of Value

Considering the nature of skeletal biology, differential preservation of skeletal material is likely to be encountered. Therefore, two alternate models that emerged from the stepwise regression procedure are summarized. In regard to the best prediction model, which has been discussed in the Chapter 3, it is apparent that the three indices within this model contain teeth from each the mandible and maxilla. Although this model produces the most significant results, these alternate models reflect varied combinations of teeth within their calculations.

Depending on the differential preservation encounter, particular fragments of a jaw or a disarticulated mandible may be encountered during a recovery. This may be due to varied environmental conditions characteristic of the area in which the skeletal material was located, or in other cases, particular portions of a jaw may simply not be within the proximity of the recovery zone. Therefore, the alternate models and their satisfied equations are available within **Appendix G** and **Appendix H** in the case that they may be of value for these types of situations. The information accompanying these equations is the Model Summary, ANOVA and Coefficients output. This information is referred to as alternate Model A and B respectively. Model A contains a predictor variable comprised of maxillary teeth. Model B contains predictor variables comprised of both maxillary teeth and mandibular teeth.

Chapter 5: Conclusion

Applying the Model Within the Field

The assessment of the terminal component of tooth loss does support a productive evaluation in determining age at death estimation, despite the fact that dental parameters associated with adult dentition become less informative at this time. Conclusions of this study were empirically supported by indices illustrating functional interdependence, which likewise coincided with previous theory based on the genetic predisposition of teeth. The disciplines of paleodemography, historic anthropology and forensic science would benefit from the application of this model within an investigation of age estimation.

Dental Anthropology Issues and Thesis Background Research

The permanent dentition serve to function through the reproductive years of life, while their services generally diminish in the post-reproductive years. Dahlberg (1964) explains that man's physical equipment, inclusive of teeth, prior to civilization was not subjected to selective factors demanding use beyond the age range of the forties. Even though teeth are sturdy, he suggests there are new and unanticipated problems accompanying present-day circumstances. This is certainly true, as society evolves amidst a magnitude of coalescing circumstances inherent to modernization.

The assessment of teeth becomes perplexing due to these interactions. In this case, a researcher is exposed to an array of contingent circumstances due to the physiology of the dentition and the gradations encountered during the aging process. As other studies have suggested (Gustafson, 1950; Johanson, 1971), I too deem from the results of this study that a multivariate approach best satisfies the investigation of determining age at death. Statistical evaluation performed in this research, benefits from an estimation that considers more than one tooth, since it alleviates tendencies for any bias concerning "local influences and their effect on the changes" (Johanson, 1971:105). This same multivariate approach extends itself to the incorporation of more than one type of skeletal age indicator being used in cases where it is possible, to determine age at death (Lovejoy et al., 1985). This study generates an Adj. R^2 value of .38 while an unexplained variance remains at approximately .62. The model itself is a resourceful aid and perhaps coupling it with other previously established techniques would further reduce the uncertainties associated with approximating adult age at death.

All teeth seemed worthy of consideration within this investigation. The exclusion of the third molars or any other tooth in particular may hold distinguishable argument in being left of the analysis. In fact, in light of reviewing third molar agenesis, I decided to include third molars within this study. My future plans include initiating a more intensive academic review of this phenomena and its prevalence across sex and "race". At this point, time constraints limited my opportunity to delve further into this pursuit.

Historical dental anthropology and forensic dental applications were the primary focus of the background research conducted for this study. This review was also inclusive of an array of age estimation techniques and their statistical methodology. It too included supplemental constituents of sex, "race", oral aspects of aging (biological and sociological) and molar agenesis.

Future Research

As was implied above, it seems that molar agenesis should be reviewed in light of its magnitude in altering results. Beyond this aspect, assessing alternate sub-samples comprised of the opposing sex and/or a different "race" would be essential for empirical validation. Model refinement is most likely inevitable due to the multitude of attributes that will undoubtedly arise as a variety of sub samples are considered.

I hope that this model serves to aid those in academia and professional arenas as it provides a glimpse across a sub-sample of humanity. Given that there was little material to review on the exact topic of tooth loss and age estimation per se, it proved valuable to pursue information across disciplines. This type of preparation was extremely beneficial in propelling my research efforts. It leads me to feel that additional insights pertaining to this model, whether they are from an anthropological perspective or from an alternate discipline, should be explicated in light of enhancing the model's transferability.

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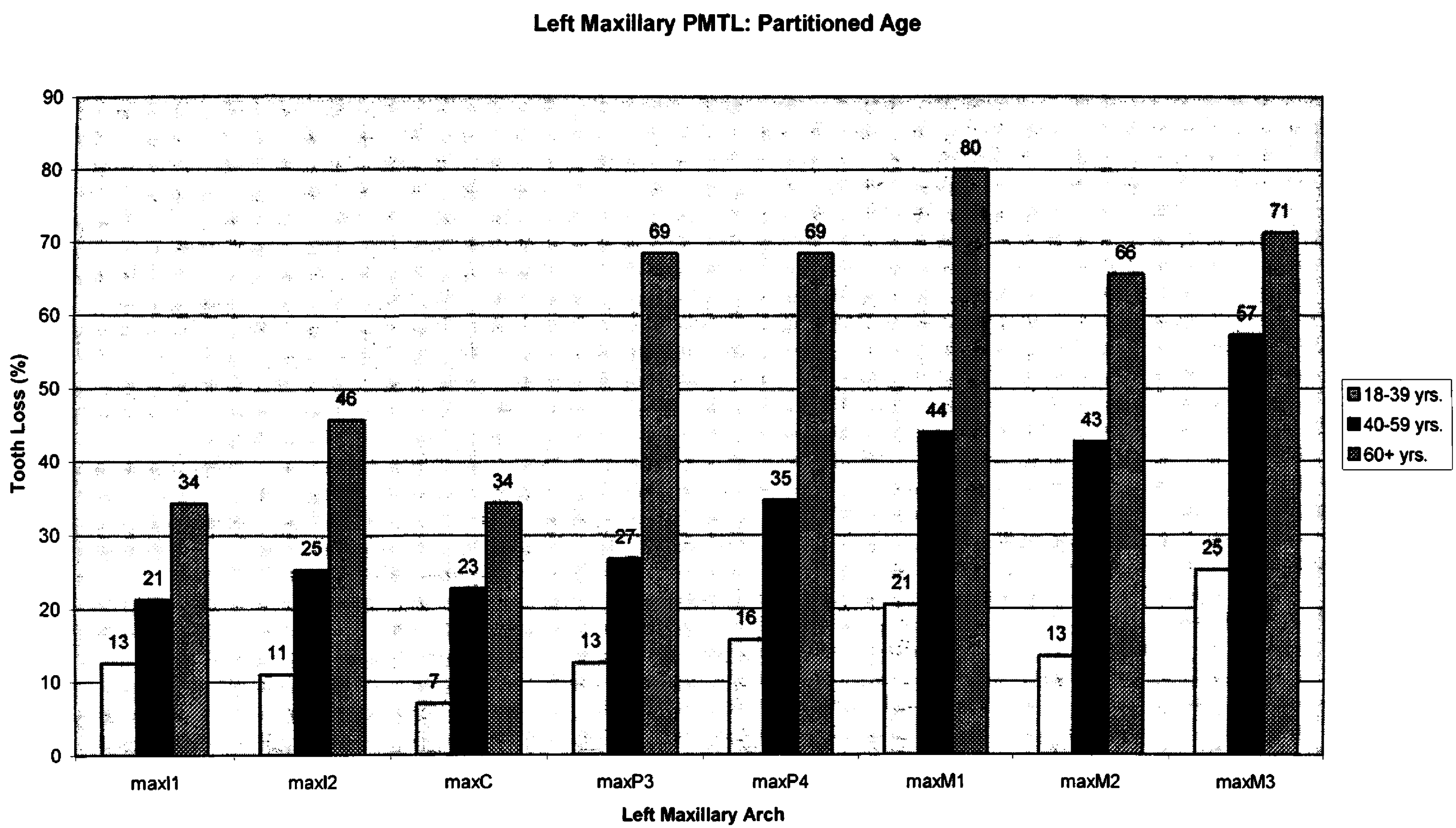
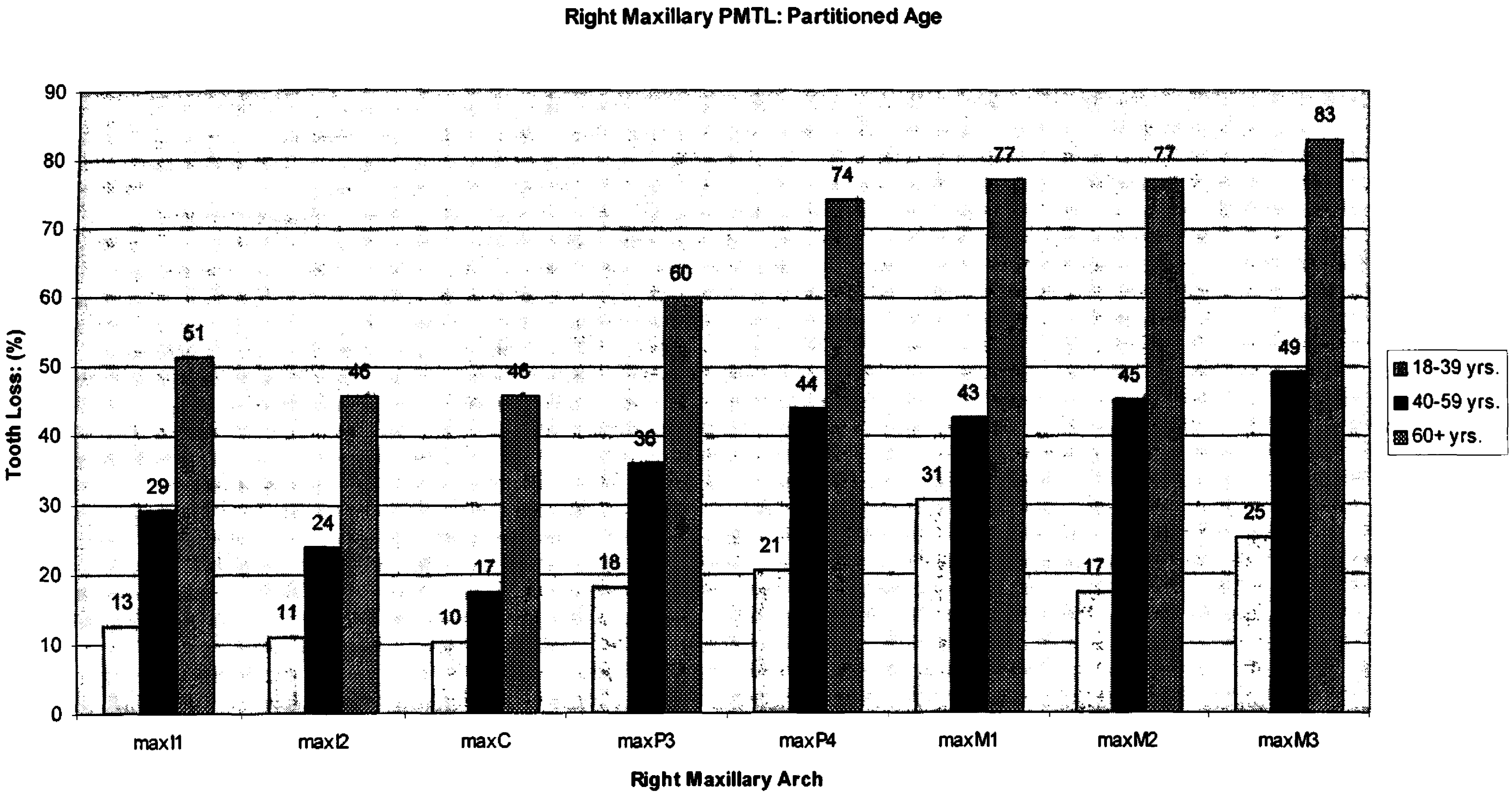
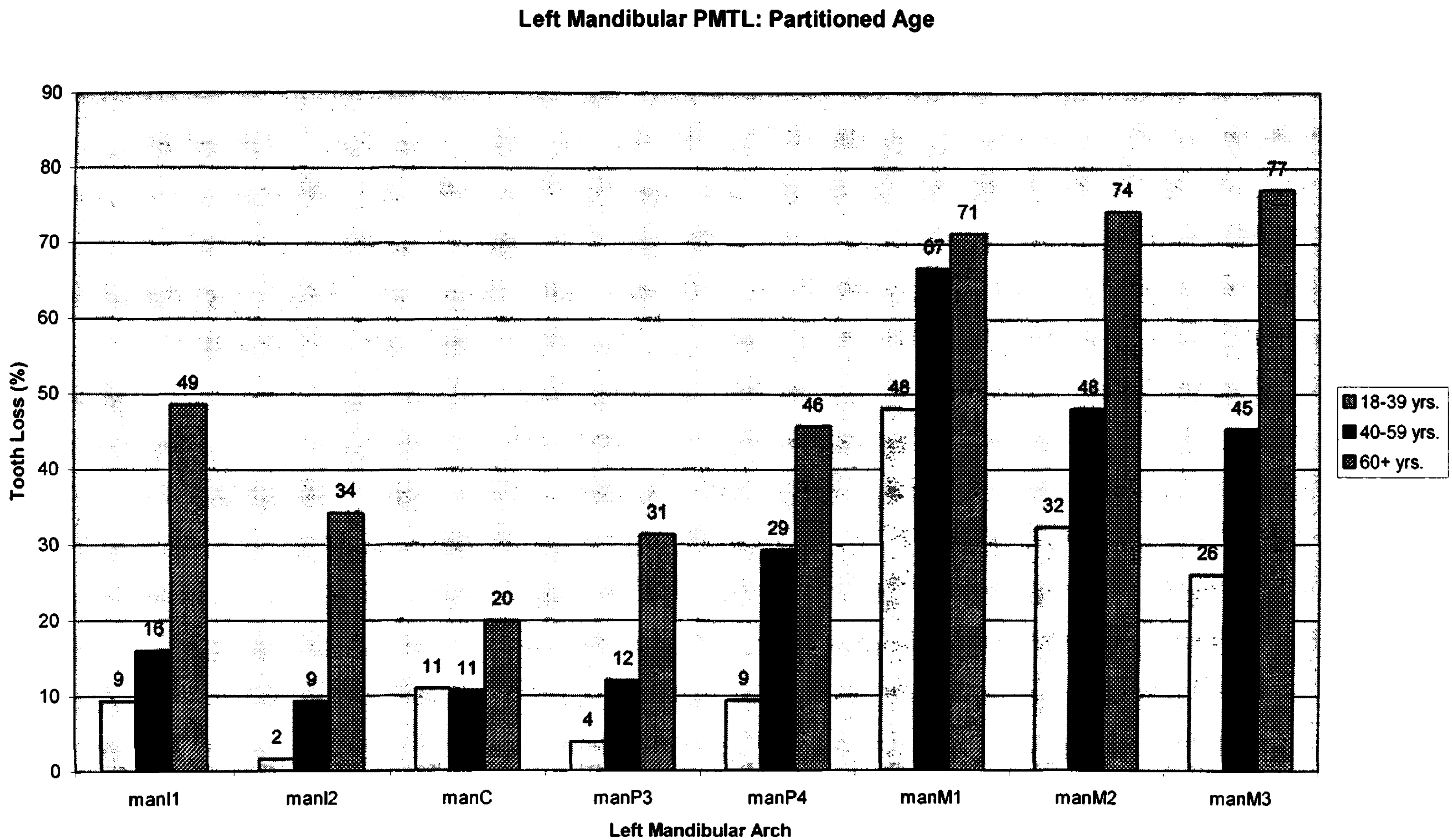
Appendix A1: Left Maxillary PMTL- Partitioned Age



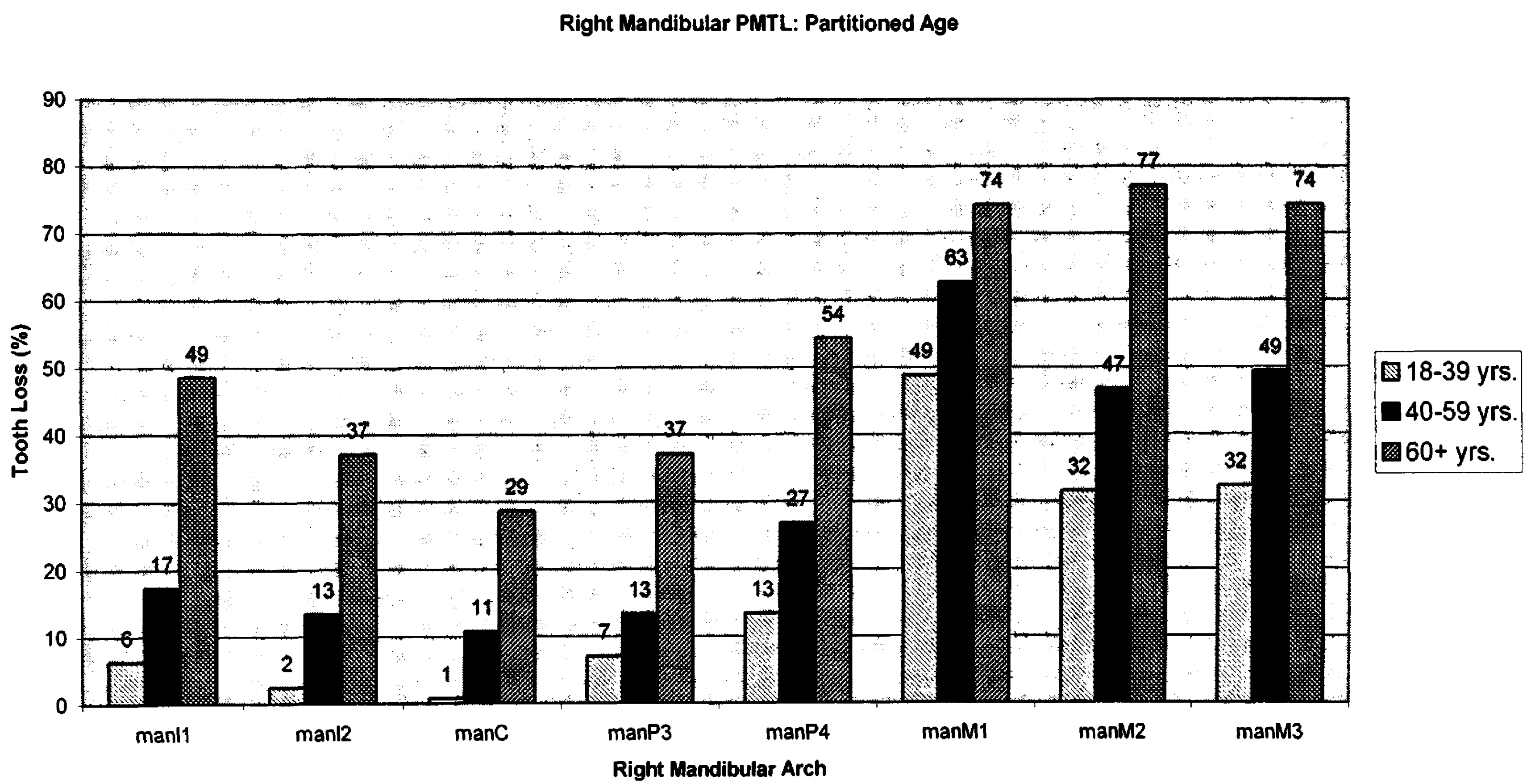
Appendix A2: Right Maxillary PMTL- Partitioned Age



Appendix A3: Left Mandibular PMTL- Partitioned Age



Appendix A4: Right Mandibular PMTL-Partitioned Age



Appendix B: Unrotated Component Matrix- Initial VFA Run

Component Matrix[a]

	Component						
	1	2	3	4	5	6	7
right man I1	.721	-.395				-.344	
right manI2	.706	-.473					
right man C	.698	-.377					
left max M2	.663						
left max P3	.662				.326		
left max I2	.658		-.304				
right max I2	.647	.307	-.455				
left max C	.646		-.364				
right max P3	.637						
left man I1	.633	-.426				-.341	
right max C	.626		-.325				
left man M3	.624		.310				
left man I2	.624	-.565					
right max I1	.623		-.416				
left max I1	.620		-.474				
left max P4	.615				.424		
right max P4	.608				.308		
right man P3	.606	-.356					
left man P3	.600	-.392					
right max M2	.580						
left man P4	.575						
right max M3	.572				-.313		
left max M1	.572						
left max M3	.561						
right man M2	.554			.381			
left man M2	.550			.379			
right man M3	.544						.307
right max M1	.488						.316
left man M1	.418			.631	.341		
right man M1	.459			.585	.400		
right man P4	.545					.585	
left man C	.381	-.365					.589

Extraction Method: Principal Component Analysis.

a. 7 components extracted.

Appendix C: Unrotated Component Matrix- Final VFA Run

Component Matrix[a]

	Component				
	1	2	3	4	5
right man I1	.717	.510			
left max I2	.698				
left max C	.682				
right manI2	.680	.515			
right max I2	.676	-.430	-.321		
right max P3	.670				
left max P3	.669				-.335
left max I1	.649	-.341	-.359		
right max I1	.646	-.343	-.320		
right max C	.643	-.320			
left man M3	.639		.331		
right max P4	.631		.373		-.358
left max P4	.629				-.443
left man I1	.628	.499	-.307		
right max M3	.592				.451
left max M3	.588		.349		.310
left man I2	.582	.560			
right max M2	.575				
left max M1	.573				
right man M3	.548				.408
left man M1	.417			.801	
right man M1	.458			.765	

Extraction Method: Principal Component Analysis.

a. 5 components extracted.

Appendix D: Detailed Descriptions of Additional Post-Hoc Methods: Multiple Comparison Tests

HOCGP2A was initially divided into six groups. The sixth group represents the complete absence of these teeth. The Levene statistic reveals a significance value of .001, which is not greater than 0.05, suggesting that a violation has occurred for the test of homogeneity of variance. On the other hand, there was a statistically significant difference at the $p \leq 0.05$ level in age at death scores for the six groups of PMTL [$\underline{F}$ (5,231)= 20.7870, $p \leq 0.05$]. In addition, the actual difference in mean scores between the groups was large. The effect size, calculated using eta squared, was .31. While this index received statistical significance for at least some of these tests, its levels were scaled.

HOCGP3A was initially divided into five groups. The fifth group represents the complete absence of these teeth. The Levene statistic reveals a significance value of .131, which is greater than 0.05, suggesting that no violation occurred for the test of homogeneity of variance. There was a statistically significant difference at the $p \leq 0.05$ level in age at death scores for the five groups of PMTL [$\underline{F}$ (4,232)= 12.2326, $p \leq 0.05$]. In addition to reaching statistical significance, the actual difference in mean scores between the groups was large. The effect size, calculated using eta squared, was .17. While this index received statistical significance for these tests, its levels were scaled.

HOCGP4A was initially divided into six groups. The sixth group represents the complete absence of these teeth. The Levene statistic reveals a significance value of .001, which is not greater than 0.05, suggesting that a violation has occurred for the test of homogeneity of variance. On the other hand, there was a statistically significant difference at the $p \leq 0.05$ level in age at death scores for the six groups of PMTL [$\underline{F}$ (5,231)= 20.2391, $p \leq 0.05$]. In addition, the actual difference in mean scores between the groups was large. The effect size, calculated using eta squared, was .30. While this index received statistical significance for at least some of these tests, its levels were scaled.

HOCGP5A was initially divided into three groups. The third group represents the scenario of complete absence of these teeth. The Levene statistic reveals a significance value of .090, which is greater than 0.05, suggesting that no violation occurred for the test of homogeneity of variance. There was a statistically significant difference at the $p \leq 0.05$ level in age at death scores for the three groups of PMTL [$\underline{F}$ (2,234)= 5.2930, $p \leq 0.05$]. The actual difference in mean scores between the groups was rather small. The effect size, calculated using eta squared, was .04. While this index received statistical significance for these tests, its levels were scaled.

Appendix E: Post-Hoc Scale Values & Actual Values within Predictor Variables

Recode: Scale Values	**Actual Values within Predictor Variables**
HOCGP1A	***Max R/L I1, I2 and C***
0	0 teeth present
1	1-4 teeth present
2	5-6 teeth present
HOCGP2A	***Max L/R P3, P4 and LM1***
0	0 teeth present
1	1-3 teeth present
2	4-5 teeth present
HOCGP3A	***Man L/R I1 and I2***
0	0-1 teeth present
1	2-3 teeth present
2	4 teeth present
HOCGP4A	***All M3's and Rmax M2***
0	0 teeth present
1	1-3 teeth present
2	4 teeth present
3	5 teeth present
HOCGP5A	***Man L/R M1***
0	0 teeth present
1	1-2 teeth present

Appendix F: Stepwise Regression Output

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
	.627[c]	.393	.385	11.8483

c. Predictors: (Constant), HOCGP2A, HOCGP4A, HOCGP3A

d. Dependent Variable: recorded age at death

ANOVA[d]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	21150.075	3	7050.025	50.221	.000[c]
Residual	32708.819	233	140.381		
Total	53858.895	236			

c. Predictors: (Constant), HOCGP2A, HOCGP4A, HOCGP3A

d. Dependent Variable: recorded age at death

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
	B	Std. Error	Beta			Zero-order	Partial	Part
(Constant)	62.806	2.276		27.595	.000			
HOCGP2A	-6.866	1.366	-.325	-5.026	.000	-.552	-.313	-.257
HOCGP4A	-4.255	.868	-.306	-4.903	.000	-.535	-.306	-.250
HOCGP3A	-2.828	1.398	-.121	-2.022	.044	-.407	-.131	-.103

a. Dependent Variable: recorded age at death

This model satisfies the following equation:

Y= 62.8 - 6.9(HOCGP2A) - 4.3(HOCGP4A) - 2.8(HOCGP3A)

Standard Error of Estimates +/- 11.8483

Appendix G: Stepwise Regression Output- Alternate Model A

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.552[a]	.304	.301	12.6258

a. Predictors: (Constant), HOCGP2A

d. Dependent Variable: recorded age at death

ANOVA[d]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	16397.607	1	16397.607	102.865	.000[a]
	Residual	37461.288	235	159.410		
	Total	53858.895	236			

a. Predictors: (Constant), HOCGP2A

d. Dependent Variable: recorded age at death

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	58.071	1.874		30.984	.000			
	HOCGP2A	-11.641	1.148	-.552	-10.142	.000	-.552	-.552	-.552

a. Dependent Variable: recorded age at death

This model satisfies the following equation:

Y= 58.1 – 11.6(HOCGP2A)

Standard Error of Estimates +/- 12.6258

Appendix H: Stepwise Regression Output- Alternate Model B

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
2	.618[b]	.382	.377	11.9262

b. Predictors: (Constant), HOCGP2A, HOCGP4A

d. Dependent Variable: recorded age at death

ANOVA[d]

Model		Sum of Squares	df	Mean Square	F	Sig.
2	Regression	20575.926	2	10287.963	72.331	.000[b]
	Residual	33282.968	234	142.235		
	Total	53858.895	236			

b. Predictors: (Constant), HOCGP2A, HOCGP4A

d. Dependent Variable: recorded age at death

Coefficients[a]

		Unstandardized Coefficients		Standardized Coefficients			Correlations		
Model		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part
2	(Constant)	59.970	1.805		33.229	.000			
	HOCGP2A	-7.789	1.296	-.369	-6.008	.000	-.552	-.366	-.309
	HOCGP4A	-4.627	.854	-.333	-5.420	.000	-.535	-.334	-.279

a. Dependent Variable: recorded age at death

This model satisfies the following equation:

Y= 60.0 - 7.8(HOCGP2A) – 4.6(HOCGP4A)

Standard Error of Estimates +/- 11.9262