Forensic Dentistry and its Application in Age Estimation from the Teeth using a Modified Demirjian System

Matthew R. B. Blenkin, BDSc

A thesis submitted in fulfilment of the requirements for the degree of

MASTER OF SCIENCE in DENTISTRY

Community Oral Health and Epidemiology

Faculty of Dentistry

The University of Sydney

Australia

2005
In loving memory of my son
James Matthew Blenkin
Abstract

The estimation of age at time of death is often an important step in the identification of human remains. If this age can be accurately estimated, it will significantly narrow the field of possible identities that will have to be compared to the remains in order to establish a positive identification. Some of the more accurate methods of age estimation, in the juvenile and younger adult, have been based on the assessment of the degree of dental development as it relates to chronological age. The purpose of this current study was to test the applicability of one such system, the Demirjian system, to a Sydney sample population, and to develop and test age prediction models using a large sample of Sydney children (1624 girls, 1637 boys). The use of the Demirjian standards resulted in consistent overestimates of chronological age in children under the age of 14 years by as much as a mean of 0.97 years, and underestimates of chronological age in children over 14 years by as much as a mean of 2.18 years in 16 year-old females. Of the alternative predictive models derived from the Sydney sample, those that provided the most accurate age estimates are applicable for the age ranges 2-14 years, with a coefficient of determination value of R-square=0.94 and a 95% confidence interval of ±1.8 years. The Sydney based standards provided significantly different and more accurate estimates of age for that sample when compared to the published standards of Demirjian.
Acknowledgments

I wish to acknowledge and thank a number of people for their contribution towards the research and preparation of this thesis:

Associate Professor Chris Griffiths, Staff Specialist, Department of Oral Medical and Surgical Sciences, Westmead Centre for Oral Health, for his mentoring, guidance and support. His willingness to assist me and to place his many resources at my disposal is much appreciated.

Associate Professor Wendell Evans, Head of Discipline, Community and Oral Health and Epidemiology, for his guidance, advice and editorial assistance in completing this thesis. His time and patience were much appreciated.

Associate Professor David Grayson, Postgraduate Co-ordinator, School of Psychology, University of Sydney for all his assistance, patience and generosity in guiding me through the statistical analysis in this work.

Dr Denise Donlon, Lecturer, Department of Anatomy and Histology, University of Sydney, for her guidance and assistance in completing the thesis.

Dr Russell Lain, Staff Specialist, Sydney Dental Hospital, for his editorial expertise.

Dr Nec Andrews, Visiting Dental Officer, Westmead Dental Hospital, for his contribution to the analysis of the orthopantomagrams.

Westmead Dental Hospital staff, specifically Dawn Romero, Patsie Daly and Bruce Waters for their assistance in obtaining records and duplicating radiographs.

The various Senior Dentists within the NSW School Dental Service; Dr Olga Gluhin at Dee Why, Dr Rathi Selvarajah at Marrickville, Dr Burt Kusic at Daceyville, and Dr’s Sue Buchannan & Ian Djokobi at the Sydney Dental Hospital, for their cooperation in providing me with access to radiographs.

Finally, my wife, Katie Blenkin for her loving support, her extraordinary patience and understanding, and for her innumerable hours of editing. Thank you.
Table of Contents

INDEX VI
LIST OF TABLES XI
LIST OF FIGURES XV
LIST OF ABREVIATIONS XVIII
CHAPTER 6

TOOTH DEVELOPMENT AND AGE ESTIMATION

6.1 CHRONOLOGY OF TOOTH DEVELOPMENT

6.2 VARIATION IN THE TIMING AND RATE OF TOOTH DEVELOPMENT

6.2.1 GENETIC FACTORS

6.2.1.1 Racial Variation in Growth

6.2.2 NON-GENETIC FACTORS

6.2.2.1 Nutrition and Socio-economic Status

6.2.2.4 Fluoride

6.2.2.5 Birth Weight

6.2.2.6 Congenital Conditions

6.2.2.7 Medical Treatment

6.2.3 SEX

6.2.4 AGE

6.2.5 A CONSTANT RATE OF DEVELOPMENT?

6.3 METHODS OF AGE ESTIMATION BASED ON TOOTH DEVELOPMENT

6.3.1 Logan & Kronfeld

6.3.2 Schour & Massler

6.3.3 Gleiser & Hunt

6.3.4 Nolla

6.3.5 Fanning

6.3.6 Moorrees, Fanning and Hunt

6.3.7 Wolanski

6.3.8 Calonius, Lunin and Stout

6.3.9 Liliequist & Lundberg

6.3.10 Demirjian, Goldstein and Tanner

6.3.11 Gustafson & Koch

6.3.12 Anderson, Thompson and Popovich

6.3.13 Ciapparelli

6.3.14 Mörnstad, Staaf & Welander

6.3.15 Liversidge

CHAPTER 7

THE DEMIRJIAN SYSTEM

7.1 Description of the Demirjian System

7.2 Validation Studies of the Demirjian System
CHAPTER 8

MATERIALS & METHOD

8.1 MATERIALS 195

8.2 METHOD 198

8.2.1 DATA COLLECTION 198
DEMI RJIAN SYSTEM 198
  8.2.1.1 Pre-calibration of Examiner 198
  8.2.1.2 Assessment of Attained Stages of Development 199
  8.2.1.3 Assessment of Inter-Observer Error 200
  8.2.1.4 Assessment of Intra-Observer Error 201
  8.2.1.5 Conversion of Assessed Stages of Development to Demirjian Maturity Score (DMS) 202
  8.2.1.6 Conversion of Assessed Stages of Development to Simple Maturity Score (SMS) 202
  8.2.1.7 Mean Ages of Scores 203
SCHOUR AND MASSLER SYSTEM 203
  8.2.1.8 Schour and Massler Method of Estimation of Age 203

8.2.2 DATA ANALYSIS 205
  8.2.2.1 Calculation of Chronological Age (CA) 206
  8.2.2.2 The Development and Validation Samples 206
  8.2.2.3 Age Estimates According to the Demirjian System 206
  8.2.2.4 Age Estimates According to Alternative Models 207
  8.2.2.5 Construction of Final Predictive Models 211

CHAPTER 9

RESULTS

9.1 DESCRIPTION OF DATA 214
  9.1.1 Assessment of Attained Stages of Development and Calculation of Chronological Age (CA) 214
  9.1.2 Assessment of Inter-observer Error 214
  9.1.3 Assessment of Intra-Observer Error 219
  9.1.4 Demirjian Maturity Score (DMS) 224
  9.1.5 Simple Maturity Score (SMS) 226
  9.1.6 Simple maturity score by age and sex 228

9.2 DATA ANALYSIS 230
  9.2.1 Age Estimates According to the Demirjian System 230
  9.2.2 Age Estimates According to Alternative Models 231
  9.2.3 Construction of Final Predictive Models 244
CHAPTER 10

DISCUSSION & CONCLUSION

10.1 Discussion 247
   10.1.1 Choice of Method 247
   10.1.2 Inter- & Intra-observer Error 248
   10.1.3 Applicability of the Published Demirjian Standards 252
   10.1.4 The Simple Maturity Score 253
   10.1.5 Regression Analysis 254
   10.1.6 Comparison Between Systems 256
   10.1.7 Chosen Models 259
   10.1.8 Description of Confidence Intervals 261
   10.1.9 Biological Variation in Dental Development 261
   10.1.10 Global Variation in Dental Development 263
   10.1.11 Limitations 265
   10.1.12 Future Directions 269

10.2 Conclusion 271
   Recommendation 274

CHAPTER 11

AGE ESTIMATION USING SMS

Age Estimation using SMS 275

REFERENCES 277

APPENDIX

A1 Data Sheet A1
A2 Collected Data A2
A3 Development of Regression Models A4
A4 Inter-Observer Agreement Results A8
A5 Intra-Observer Agreement Results A9
B1 Final Predictive Models B1
B2 SMS Conversion & Confidence Interval Tables B3
C1 Ethics Approval Documentation C1
List of Tables

TABLE 6.1: TIME OF BEGINNING OF CALCIFICATION OF THE PERMANENT TEETH AS REPORTED BY VARIOUS RESEARCHERS. THE 'AUTHOR'S FINDINGS' REFER TO THOSE OF LOGAN AND KRONFELD (FROM LOGAN AND KRONFELD, '33).

TABLE 6.2: AGE (YEARS) OF ATTAINMENT OF MINERALIZATION STAGES OF TEETH OF THE MALE MANDIBLE (FROM ANDERSON, THOMPSON AND POPOVICH, '76)

TABLE 6.3: COMPARISON OF DENTAL DEVELOPMENT OF MANDIBULAR SECOND PERMANENT MOLAR USING 14 STAGES OF MOORREES ET AL. X (BAR)= MEAN AGE, AND SD= STANDARD DEVIATION (FROM CIAPPARELLI 92).

TABLE 7.1: CONVERSION TABLE – SELF-WEIGHTED SCORES FOR DENTAL STAGES – MALE (FROM DEMIRJIAN 1976)

TABLE 7.2: CONVERSION TABLE – SELF-WEIGHTED SCORES FOR DENTAL STAGES – FEMALE (FROM DEMIRJIAN 1976)

TABLE 7.3: CONVERSION TABLE – DEMIRJIAN MATURITY SCORE TO DENTAL AGE – MALE & FEMALE (FROM DEMIRJIAN 1976)

TABLE 8.1: DISTRIBUTION OF CASES ANALYSED BY LOCATION

TABLE 8.2: DISTRIBUTION OF CASES ANALYSED BY AGE GROUP AND SEX

TABLE 8.3: KAPPA VALUES AND THEIR ASSOCIATED DEGREE OF RELIABILITY (FROM LANDIS AND KOCH 1977)

TABLE 8.4: CONVERSION TABLE – ALPHA-NUMERIC STAGE TO MATURITY SCORE (AFTER DEMIRJIAN 1976)

TABLE 9.1: DISTRIBUTION OF DISAGREEMENTS BETWEEN OBSERVERS, BY TOOTH TYPE, AND BY MAGNITUDE OF DISAGREEMENT.

TABLE 9.2: DISTRIBUTION OF TOOTH DEVELOPMENT STAGES OF ALL 7 RIGHT MANDIBULAR TEETH (47-41) AS ASSESSED BY TWO EXAMINERS. NUMBERS IN PARENTHESES ARE CHANCE-EXPECTED FREQUENCIES OF AGREEMENT, E.G. 3.5=43X42/518.

TABLE 9.3: DISTRIBUTION OF TOOTH DEVELOPMENT STAGE OF TOOTH 47 AS ASSESSED BY TWO EXAMINERS. NUMBERS IN PARENTHESES ARE CHANCE-EXPECTED FREQUENCIES OF AGREEMENT, E.G. 5.39=19X21/74.

TABLE 9.4: KAPPA VALUES, INDICATING LEVELS OF AGREEMENT OF THE STAGE OF DEVELOPMENT BETWEEN TWO OBSERVERS FOR EACH TOOTH TYPE

TABLE 9.5: BETWEEN EXAMINER AGREEMENT CONCERNING THE STAGE OF DEVELOPMENT 'A' ACROSS ALL 7 RIGHT MANDIBULAR TEETH (47-41), DICHTOMISED AS A/NOT A (FROM TABLE 9.2). NUMBERS IN PARENTHESES ARE CHANCE-EXPECTED FREQUENCIES OF AGREEMENT, E.G. 0.63=18X18/518.
TABLE 9.6: KAPPA VALUES INDICATING THE LEVELS OF AGREEMENT BETWEEN TWO OBSERVERS FOR EACH STAGE OF TOOTH DEVELOPMENT ACROSS ALL 7 RIGHT MANDIBULAR TEETH (47-41)

TABLE 9.7: BETWEEN EXAMINER AGREEMENT CONCERNING THE STAGE OF DEVELOPMENT 'A' FOR TOOTH 47, DICHOTOMISED AS A/NOT A (FROM TABLE 9.3). KAPPA=0.39

TABLE 9.8: KAPPA VALUES INDICATING THE LEVELS OF AGREEMENT BETWEEN TWO OBSERVERS FOR EACH STAGE OF TOOTH DEVELOPMENT BY INDIVIDUAL TOOTH TYPE

TABLE 9.9: DISTRIBUTION OF DISAGREEMENTS BETWEEN REPEATED OBSERVATIONS BY THE SAME OBSERVER, BY TOOTH TYPE, AND BY MAGNITUDE OF DISAGREEMENT

TABLE 9.10: DISTRIBUTION OF TOOTH DEVELOPMENT STAGES OF ALL 7 RIGHT MANDIBULAR TEETH (47-41) AS ASSESSED IN DUPLICATE OBSERVATIONS BY THE SAME OBSERVER. NUMBERS IN PARENTHESES ARE CHANCE-EXPECTED FREQUENCIES OF AGREEMENT, E.G. 0.57=26X28/1267.

TABLE 9.11: DISTRIBUTION OF TOOTH DEVELOPMENT STAGE OF TOOTH 47 AS ASSESSED IN DUPLICATE OBSERVATIONS BY THE SAME OBSERVER. NUMBERS IN PARENTHESES ARE CHANCE-EXPECTED FREQUENCIES OF AGREEMENT, E.G. 1.41=16X16/181.

TABLE 9.12: KAPPA VALUES, INDICATING LEVELS OF AGREEMENT OF THE STAGE OF DEVELOPMENT IN DUPLICATE OBSERVATIONS, BY THE SAME OBSERVER FOR EACH TOOTH TYPE


TABLE 9.14: KAPPA VALUES INDICATING THE LEVELS OF AGREEMENT IN DUPLICATE OBSERVATIONS BY THE SAME OBSERVER, FOR EACH STAGE OF TOOTH DEVELOPMENT ACROSS ALL 7 RIGHT MANDIBULAR TEETH (47-41)

TABLE 9.15: INTRA-EXAMINER AGREEMENT CONCERNING THE STAGE OF DEVELOPMENT 'A' FOR TOOTH 47, DICHOTOMISED AS A/NOT A (FROM TABLE 9.11). KAPPA=0.72

TABLE 9.16: KAPPA VALUES INDICATING THE LEVELS OF AGREEMENT IN DUPLICATE OBSERVATIONS BY THE SAME OBSERVER, FOR EACH STAGE OF TOOTH DEVELOPMENT BY INDIVIDUAL TOOTH TYPE

TABLE 9.17: MALE MEAN DEMIRJIAN MATURITY SCORE (COLUMN TOTAL) DERIVED FROM TOOTH-SPECIFIC MEAN SELF-WEIGHTED SCORES, BY CHRONOLOGICAL AGE.

TABLE 9.18: FEMALE MEAN DEMIRJIAN MATURITY SCORE (COLUMN TOTAL) DERIVED FROM TOOTH-SPECIFIC MEAN SELF-WEIGHTED SCORES, BY CHRONOLOGICAL AGE.
TABLE 9.19: MALE MEAN SIMPLE MATURITY SCORE (COLUMN TOTAL) DERIVED FROM TOOTH-SPECIFIC MEAN NUMERICAL MATURITY SCORES, BY CHRONOLOGICAL AGE. 226

TABLE 9.20: FEMALE MEAN SIMPLE MATURITY SCORE (COLUMN TOTAL) DERIVED FROM TOOTH-SPECIFIC MEAN NUMERICAL MATURITY SCORES, BY CHRONOLOGICAL AGE. 227

TABLE 9.21: MEAN DIFFERENCES BETWEEN MALE AND FEMALE CHRONOLOGICAL AGE, T-SCORES AND ASSOCIATED P-VALUES BY SMS. THE T-CRITICAL VALUES ARE GIVEN FOR THE ASSOCIATED SAMPLE SIZES WITH P<0.05. 229

TABLE 9.22: MEAN OVERESTIMATES OF PREDICTED AGE BY CHRONOLOGICAL AGE (CA) AND SEX, WHERE PREDICTED AGE IS CALCULATED USING THE DEMIRJIAN MATURITY SCORE. 230

TABLE 9.25: REGRESSION CALCULATION OUTPUT FOR MALE DEVELOPMENT SAMPLE WHERE CHRONOLOGICAL AGE WAS REGRESSED ON SIMPLE MATURITY SCORE TO INCREASING POWERS. IN THIS FINAL SELECTED CASE THE PREDICTORS WERE SMS, SMS$^2$, SMS$^3$, SMS$^4$, AND SMS$^5$. 232

TABLE 9.26: REGRESSION CALCULATION OUTPUT FOR FEMALE DEVELOPMENT SAMPLE WHERE CHRONOLOGICAL AGE WAS REGRESSED ON SIMPLE MATURITY SCORE TO INCREASING POWERS. IN THIS FINAL SELECTED CASE THE PREDICTORS WERE SMS, SMS$^2$, SMS$^3$, SMS$^4$, AND SMS$^5$. 234

TABLE 9.27: REGRESSION CALCULATION OUTPUT FOR MALE TRUNCATED DEVELOPMENT SAMPLE WHERE CHRONOLOGICAL AGE WAS REGRESSED ON SIMPLE MATURITY SCORE TO INCREASING POWERS. IN THIS FINAL SELECTED CASE THE PREDICTORS WERE SMS, SMS$^2$, AND SMS$^3$. 236

TABLE 9.28: REGRESSION CALCULATION OUTPUT FOR FEMALE TRUNCATED DEVELOPMENT SAMPLE WHERE CHRONOLOGICAL AGE WAS REGRESSED ON SIMPLE MATURITY SCORE TO INCREASING POWERS. IN THIS FINAL SELECTED CASE THE PREDICTORS WERE SMS, SMS$^2$, AND SMS$^3$. 238


TABLE 9.30: T-TEST STATISTICS IN RELATION TO OVERALL MEAN PREDICTION ERRORS FOR GIVEN MODELS. 243

TABLE 9.32: 95% CONFIDENCE INTERVALS (IN YEARS) FOR EACH AGE GROUP BY SEX FOR THE FINAL PREDICTION MODELS (SMS-55). FOR AN AGE OF A MALE THAT IS PREDICTED WITHIN THE 2 YEAR AGE GROUP THE 95% CONFIDENCE INTERVAL WILL BE THAT PREDICTED AGE ±0.7 YEARS. 246
TABLE A2.1: EXAMPLE OF INITIAL RAW DATA COLLECTION; WHERE PROJECT KEY ID IS THE CASE ASSIGNED UNIQUE IDENTIFIER FOR EACH CASE, 48-41 ARE THE TEETH WITH THEIR ASSOCIATED ASSESSED LEVEL OF DEVELOPMENT, S & M IS THE ESTIMATED AGE OF THE CASE USING THE SCOUR & MASSLER CHARTS, DOB IS DATE OF BIRTH (OBTAINED FROM FILMS OR RECORDS), AND DOX IS DATE OF OPG EXPOSURE (TAKEN FROM OPG FILM LABEL).

TABLE A2.2: EXAMPLE OF DATA COLLECTED; IN ADDITION TO THE DATA IN TABLE A2.1, DATES OF BIRTH AND OPGS WERE SOURCED AND USED TO CALCULATE AGE OF CASES AT TIME OF OPG EXPOSURE; ALPHABETIC TOOTH SCORES CONVERTED TO DMS AND AGE PREDICTIONS MADE USING THE STANDARDS OF DEMIRJIAN (CPA).

TABLE A4: EXAMPLE OF RAW RESULTS COLLECTED FROM TWO SEPARATE ANALYSES UNDERTAKEN BY TWO SEPARATE RESEARCHERS. THE FIRST ROW OF EACH CASE IS ONE SET OF OBSERVATIONS, BEING THE ASSESSED LEVELS OF DENTAL DEVELOPMENT PER TOOTH; THE SECOND ROW IS THE OTHER SET OF A OBSERVATIONS FROM THE SECOND RESEARCHER. THE THIRD ROW IN EACH CASE INDICATES THE MAGNITUDE OF ANY DISAGREEMENT BETWEEN THE TWO OBSERVATIONS. THESE DISAGREEMENTS ARE TOTALLED BY TOOTH AND BY CASE IN THE RESPECTIVE COLUMNS.

TABLE A5: EXAMPLE OF RAW RESULTS COLLECTED FROM TWO SEPARATE ANALYSES UNDERTAKEN BY THE SAME RESEARCHER. THE FIRST ROW OF EACH CASE IS ONE SET OF OBSERVATIONS, BEING THE ASSESSED LEVELS OF DENTAL DEVELOPMENT PER TOOTH; THE SECOND ROW IS THE OTHER SET OF A RESULTS FORM A SUBSEQUENT SET OF OBSERVATIONS BY THE SAME RESEARCHER. THE THIRD ROW IN EACH CASE INDICATES THE MAGNITUDE OF ANY DISAGREEMENT BETWEEN THE TWO OBSERVATIONS. THESE DISAGREEMENTS ARE TOTALLED BY TOOTH AND BY CASE IN THE RESPECTIVE COLUMNS.

TABLE B2.1: CONVERSION TABLE – SIMPLE MATURITY SCORE (AFTER DEMIRJIAN 1976)

TABLE B2.2: SUMMARY OF 95% CONFIDENCE INTERVALS (IN YEARS) FOR EACH AGE GROUP BY SEX FOR THE FINAL PREDICTION MODELS (SMS-55).
List of Figures

FIGURE 5.1: DATES OF APPEARANCE OF CENTRES OF OSSIFICATION TO 5 YEARS-OF-AGE IN WHITE FEMALES (FROM FRANCIS ET AL., ’39). 92

FIGURE 5.2: DIAGRAMMATIC REPRESENTATION OF THE SUBDIVISIONS OF THE CRANIAL VAULT SUTURES (FROM MCKERN AND STEWART, ’57). 97

FIGURE 5.3 MODEL STANDARDS OF TODD'S 10 TYPICAL PHASES (FROM MCKERN AND STEWART ’57). 101

FIGURE 5.4: COMPONENT ANALYSIS OF THE PUBIC SYMPHYSIS IN MALES (FROM MCKERN AND STEWART ’57). 102

FIGURE 5.5: PHASES OF STRUCTURAL CHANGE IN THE CANCELLOUS BONE OF THE PROXIMAL EPIPHYSIS OF THE FEMUR (FROM ASCÁDI AND NEMESKERI, 70). 105

FIGURE 6.1: NORMS OF TOOTH FORMATION OF PERMANENT MANDIBULAR CANINES, AND PREMOLARS OF FEMALES (FROM MOORREES, FANNING AND HUNT, 63). 112

FIGURE 6.2: THE SEQUENCE OF FORMATION OF THE HUMAN DENTITION (FROM SCHOUR AND MASSLER, ’41). 149

FIGURE 6.3: STAGES OF DEVELOPMENT OF THE MANDIBULAR AND MAXILLARY TEETH (FROM NOLLA, ’60). 154


FIGURE 6.5: CHART FOR ESTIMATING DENTAL AGE IN FEMALES. FIGURES ON THE ORDI Nate OF THE GRAPH PROPER REPRESENT THE SCORES FOR ALL 10 PERMANENT TEETH USED IN THE WOLANSKI STUDY, AND IN THE INSERT FOR JUST 5 PERMANENT TEETH (FROM WOLANSKI, ’66). 162


FIGURE 6.7: DISTANCES MEASURED BETWEEN DEFINED LANDMARKS. CH, CROWN HEIGHT. DRL, LENGTH OF DISTAL ROOT IN MOLARS. MRL, LENGTH OF MESIAL ROOTS IN MOLARS. RL, ROOT LENGTH OF SINGLE-ROOTED TEETH. DAW, WIDTH OF DISTAL APEX IN MOLARS. MAW, WIDTH OF MESIAL APEX IN MOLARS. AW, WIDTH OF APEX OF SINGLE-ROOTED TEETH. 175

FIGURE 7.1: THE DEVELOPMENT STATUS OF EACH GROUP OF TEETH (FROM LEFT TO RIGHT - MOLARS, PREMOLARS, CANINES, INCISORS) IS DEFINED FOR STAGES A-H. THE DEFINITION OF EACH STAGE OF THE PERMANENT DENTITION IS BASED ON THE ASSOCIATED BIOLOGICAL CRITERIA (FROM DEMIRJIAN ’76). 184
FIGURE 9.1: MEAN AGE BY SMS (CENTRED DOTS) FOR THE ENTIRE SAMPLE. THE BLUE AND PINK LINES REPRESENT THE RANGE FOR A GIVEN SMS FOR MALES AND FEMALES RESPECTIVELY. 228

FIGURE 9.2: CHRONOLOGICAL AGE AGAINST SIMPLE MATURITY SCORE FOR THE MALE DEVELOPMENT SAMPLE. SUPERIMPOSED IS THE REGRESSION CURVE DESCRIBED IN THE SUMMARY OUTPUT TABLE 9.25 ABOVE. 232

FIGURE 9.3: CHRONOLOGICAL AGE AGAINST SIMPLE MATURITY SCORE FOR THE FEMALE DEVELOPMENT SAMPLE. SUPERIMPOSED IS THE REGRESSION CURVE DESCRIBED IN THE SUMMARY OUTPUT TABLE 9.26 ABOVE. 234

FIGURE 9.4: CHRONOLOGICAL AGE AGAINST SIMPLE MATURITY SCORE FOR THE MALE TRUNCATED DEVELOPMENT SAMPLE. SUPERIMPOSED IS THE REGRESSION CURVE DESCRIBED IN THE SUMMARY OUTPUT TABLE 9.27 ABOVE. 236

FIGURE 9.5: CHRONOLOGICAL AGE AGAINST SIMPLE MATURITY SCORE FOR THE FEMALE TRUNCATED DEVELOPMENT SAMPLE. SUPERIMPOSED IS THE REGRESSION CURVE DESCRIBED IN THE SUMMARY OUTPUT TABLE 9.28 ABOVE. 238

FIGURE 9.6: CHRONOLOGICAL AGE AGAINST SIMPLE MATURITY SCORE FOR THE MALE DEVELOPMENT SAMPLE. SUPERIMPOSED ARE THE REGRESSION CURVES FOR THE FULL SMS DATA SET (HEAVY BLUE LINE) AND THAT OF THE SMS-55 TRUNCATED DATA SET (THIN BLACK LINE). 241

FIGURE 9.7: CHRONOLOGICAL AGE AGAINST SIMPLE MATURITY SCORE FOR THE FEMALE DEVELOPMENT SAMPLE. SUPERIMPOSED ARE THE REGRESSION CURVES FOR THE FULL SMS DATA SET (HEAVY BLUE LINE) AND THAT OF THE SMS-55 TRUNCATED DATA SET (THIN BLACK LINE). 241

FIGURE 9.8: PREDICTED AGE AGAINST MATURITY SCORE FOR MALES, DERIVED FROM ENTIRE MALE SAMPLE WHERE $N=1363$ AND $Y=-2.042579201+0.416441557*X-0.009307122*X^2+0.000128194*X^3$, WHERE $Y$ IS THE PREDICTED AGE IN YEARS AND $X$ IS THE CALCULATED MATURITY SCORE. 245

FIGURE 9.9: PREDICTED AGE AGAINST MATURITY SCORE FOR FEMALES, DERIVED FROM ENTIRE FEMALE SAMPLE WHERE $N=1224$ AND USING THE REGRESSION FORMULA $Y=-1.914675804+0.4218823224*X-0.010273636*X^2+0.000141442*X^3$, WHERE $Y$ IS THE PREDICTED AGE IN YEARS AND $X$ IS THE CALCULATED MATURITY SCORE. 245

FIGURE A1.1: SAMPLE OF DATA SHEET USED TO RECORD ASSESSED STAGES OF TOOTH DEVELOPMENT, SEX, DATE OF BIRTH AND DATE OF OPG EXPOSURE FOR EACH CASE. EACH BOX LABELLED 47 TO 41 REPRESENTS THE ASSESSED LEVEL OF DEVELOPMENT FOR THE GIVEN TOOTH (FDI NOTATION). 307

FIGURE A1: CHRONOLOGICAL AGE AGAINST SIMPLE MATURITY SCORE FOR THE MALE DEVELOPMENT SAMPLE. SUPERIMPOSED IS THE REGRESSION CURVE DESCRIBED BY THE FORMULA QUOTED ON THE CHART, USING ONE REGRESSOR (SMS). A4

FIGURE A2: CHRONOLOGICAL AGE AGAINST SIMPLE MATURITY SCORE FOR THE MALE DEVELOPMENT SAMPLE. SUPERIMPOSED IS THE REGRESSION CURVE DESCRIBED BY THE FORMULA QUOTED ON THE CHART, USING TWO REGRESSORS (SMS AND SMS$^2$). A5
FIGURE A3: CHRONOLOGICAL AGE AGAINST SIMPLE MATURITY SCORE FOR THE MALE DEVELOPMENT SAMPLE. SUPERIMPOSED IS THE REGRESSION CURVE DESCRIBED BY THE FORMULA QUOTED ON THE CHART, USING THREE REGRESSORS (SMS, SMS² AND SMS³).

FIGURE A4: CHRONOLOGICAL AGE AGAINST SIMPLE MATURITY SCORE FOR THE MALE DEVELOPMENT SAMPLE. SUPERIMPOSED IS THE REGRESSION CURVE DESCRIBED BY THE FORMULA QUOTED ON THE CHART, USING FOUR REGRESSORS (SMS, SMS², SMS³ AND SMS⁴).

FIGURE A5: CHRONOLOGICAL AGE AGAINST SIMPLE MATURITY SCORE FOR THE MALE DEVELOPMENT SAMPLE. SUPERIMPOSED IS THE REGRESSION CURVE DESCRIBED BY THE FORMULA QUOTED ON THE CHART, USING FOUR REGRESSORS (SMS, SMS², SMS³, SMS⁴ AND SMS⁵).
## List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AI</td>
<td>Amelogenisis Imperfecta</td>
</tr>
<tr>
<td>CA</td>
<td>Chronological Age</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence Interval</td>
</tr>
<tr>
<td>CPA</td>
<td>Canadian Predicted Age</td>
</tr>
<tr>
<td>CT</td>
<td>Computerised Tomography</td>
</tr>
<tr>
<td>DMS</td>
<td>Demirjian Maturity Score</td>
</tr>
<tr>
<td>DVI</td>
<td>Disaster Victim Identification</td>
</tr>
<tr>
<td>LBW</td>
<td>Low Birth Weight</td>
</tr>
<tr>
<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
</tr>
<tr>
<td>NBW</td>
<td>Normal Birth Weight</td>
</tr>
<tr>
<td>NSWDOFM</td>
<td>New South Wales Department of Forensic Medicine</td>
</tr>
<tr>
<td>OPG</td>
<td>Orthopantomogram</td>
</tr>
<tr>
<td>PA</td>
<td>Predicted Age</td>
</tr>
<tr>
<td>SD</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>SEE</td>
<td>Standard Error of Estimate</td>
</tr>
<tr>
<td>SMS</td>
<td>Simple Maturity Score</td>
</tr>
<tr>
<td>VLBW</td>
<td>Very Low Birth Weight</td>
</tr>
</tbody>
</table>