DENTAL AGE RELATED TABLES FOR CHILDREN OF VARIOUS ETHNIC GROUPS IN SOUTH AFRICA

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ABSTRACT

The standard age estimation methods of Moorrees, Fanning & Hunt (1963) and that of Demirjian, Goldstein & Tanner (1973) have been shown by several authors to be inaccurate when applied to their juvenile population. This was similarly found to be true in South African children. Pantomographic radiographs of samples of South African children of White, Coloured, Indian and Black origin were used to develop dental age related tables for these ethnic groups. These dental age estimation tables were tested and are presented.

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Keywords: Age estimation, dental, radiology, juvenile

INTRODUCTION

Moorrees, Fanning and Hunt (1963) [MFH] published charts based on a radiographic survey of the development of the permanent dentition.[1] These charts indicate the average age and two standard deviations for the various developmental stages of the teeth. The range between ± two standard deviations represents an age range in which 95% of the population would be expected to reach the appropriate developmental landmark. These charts have proved useful for the assessment of a child's dental development with regard to the skeletal developmental stage and for planning orthodontic treatment. They have also been used for age estimation of skeletal remains. A study of dental maturity by Demirjian, Goldstein and Tanner (1973) [DGT] using the dental Pantomographic radiographs of 2928 boys and girls of French-Canadian ancestry between the ages of 2 and 20 years was undertaken.[2] The radiographic images of the progressive developmental stages of the 7 left mandibular teeth were allocated labels A to H and the various stages of dental development recorded for each of the age groups. Maturity scores, based on the work of Tanner, Whitehouse and Healy (1962) were developed and allotted to each tooth during its developmental stages.[3] The total of the maturity scores of the 7 teeth was then converted to tables for both boys and girls to obtain an estimated chronological age. Several authors have tested the Demirjian *et al* method against their child population groups with varying success rates.[4-17] Most of these authors found that the DGT method over-estimated the ages of their samples.[6-12, 14-17]

Research by Phillips (2008)[18] has shown that the standard tables of Moorrees, Fanning and Hunt (1963) and Demirjian, Goldstein and Tanner (1973) when used for age estimation on South African children was not as accurate as the results that were obtained by applying these methods on the original European samples.

The aim of this study was to construct dental age related tables for samples of South African children of different ethnic origins from dental record at the Dental Faculty of the University of the Western Cape and from Orthodontic practices in Durban, Kwa-Zulu Natal. The derivation of dental age related tables for the Tygerberg, Indian and African (Nguni) children described as Phillips Tables would then be tested on samples of White and Coloured children (Tygerberg); Indian children and African (Xhosa) children and the results statistically analysed.

MATERIALS AND METHODS

Dental Pantomographic radiographs were recovered from the archival records of patients treated at the Dental Faculty of the University of the Western Cape. The Tygerberg sample consisted of 1006 children of White and Coloured[19] origin. An Indian sample consisted of 234 children

obtained from the records of two Orthodontic practices in Durban, Kwa-Zulu Natal. Most of the patients undergoing orthodontic treatment are between the ages of 7 to 16 years. A Black sample which consisted of 171 Zulu children was obtained from two Orthodontic practices in Durban, Kwa-Zulu Natal. A sample of 65 Xhosa children from the Western Cape informal settlement area were obtained from the dental records of recently treated children at the Tygerberg Dental School. These data were added to the sample of Zulu children and named the Nguni sample. The patients chosen for this study had all their developing permanent teeth visible on the Pantomograph. Those with missing teeth or severe malocclusions were rejected. Pivot tables were used to derive the median age and the standard deviation at which each stage of tooth development had taken place. Dental age related tables were constructed for Tygerberg (Table 1), Indian (Table 2) and Nguni (Table 3) children. The samples were not separated into males and females.

Dental age related tables were derived, and the standard error of the mean was calculated for each sample group. The author was the only observer of the radiographic images of the developmental stages of the teeth.

A new Tygerberg sample used for this part of the study was an additional set of individuals obtained from the files of children currently undergoing dental treatment at the Dental Faculty of the University of the Western Cape. The Tygerberg sample consisted of 91 children, 70 White, 21 Coloured. The Indian and Xhosa samples were a random selection of children from the original data bases used in this study. There were 112 Indian and 62 Xhosa children respectively. The Tygerberg, Indian and Xhosa samples were analysed in the following manner: the age of each child was estimated using the MFH, the DGT methods. Then the ages of the individuals were estimated using the Phillips Tables applicable for each sample. (Phillips Table 1 was used for the Tygerberg sample, Phillips Table 2 was used for the Indian sample and Phillips Table 3 was used for the Xhosa sample). The age estimation error for each method was calculated and depicted graphically. The real ages and the errors of the estimated ages of each method were subjected to regression analysis. All r-correlation coefficients were tested for significance and in every case the p-value was significant at the $p < 0.05$ level.

Table 1: *Dental Age Related Table for Tygerberg Children (SD in years) (n = 1006)*

	I 1	I 2	C	Pm1	Pm2	M1	M2	M3
Fi								
F					4.44 (0.85)			8.85 (1.39)
Ci					4.74 (1.06)		4.13 (0.64)	9.29 (1.16)
Cco					4.97 (0.74)		4.74 (1.47)	10.40 (1.34)
Coc				3.26	4.78 (1.00)		4.75 (0.53)	10.98 (1.05)
Cr1/2			4.14	4.65 (0.65)	5.30 (0.80)		5.42 (0.82)	12.08 (1.12)
Cr3/4		3.96 (0.27)	4.70 (0.75)	5.16 (0.72)	6.21 (0.74)	3.26	6.28 (0.81)	12.62 (1.38)
Crc	4.06 (0.36)	4.74 (0.78)	5.30 (0.94)	6.29 (0.95)	7.39 (0.88)	4.04 (0.24)	7.56 (1.00)	13.38 (1.24)
Ri	4.53 (0.61)	5.27 (0.70)	6.11 (0.81)	7.13 (0.87)	8.23 (0.90)		8.29 (0.76)	14.18 (1.44)
Cli						4.70 (0.92)	8.77 (0.95)	15.09 (1.09)
R1/4	5.37 (0.65)	6.02 (0.60)	7.42 (0.94)	8.26 (0.90)	9.14 (1.17)	5.45 (0.86)	10.04 (1.00)	15.24 (0.96)
R1/2	6.07 (0.54)	6.78 (0.88)	8.52 (1.03)	9.63 (1.06)	10.45 (1.04)	6.25 (0.55)	11.05 (1.01)	
R3/4	6.89 (0.93)	7.35 (0.66)	10.00 (1.17)	10.50 (1.01)	11.09 (1.15)	7.25 (0.77)	11.73 (0.77)	
Rc	7.25 (0.58)	8.08 (0.70)	11.23 (1.10)	11.41 (0.83)	12.06 (1.02)	8.05 (0.76)	12.60 (0.91)	
A1/2	8.02 (0.68)	8.76 (0.78)	12.14 (0.96)	12.14 (0.77)	12.72 (1.16)	9.10 (0.85)	14.04 (1.06)	
Ac								

The Ac stage is omitted for age estimation. Only teeth that have not fully developed are used to estimate the age of the individual. The median age at which the stage of calcification is visible and the standard deviation are shown in brackets.

Table 2: *Dental Age Related Table for Indian Children (SD in years) (n = 234)*

	I 1	I 2	C	Pm1	Pm2	M1	M2	M3
Fi								
F								9.71
Ci								9.78 (1.06)
Cco								10.81 (1.33)
Coc								11.32 (1.10)
Cr1/2							6.87	10.86 (0.84)
Cr3/4					6.97 (0.14)		8.75 (1.30)	12.40 (1.26)
Crc				7.07	9.19 (0.92)		8.64 (1.10)	13.36 (1.18)
Ri				8.41 (1.30)	9.33 (1.01)		8.34 (0.86)	
Cli							9.59 (0.84)	14.09 (0.97)
R1/4			9.11 (0.87)	9.20 (0.87)	9.85 (1.00)		10.28 (1.15)	14.95 (0.68)
R1/2	6.76 (0.15)	7.72 (0.92)	9.64 (1.14)	10.36 (0.82)	10.40 (0.92)		11.04 (0.83)	15.30 (1.54)
R3/4	8.39 (0.66)	8.71 (0.88)	10.37 (1.08)	10.96 (1.52)	11.40 (1.22)	8.29 (1.93)	12.05 (1.12)	
Rc	9.58 (1.15)	9.57 (1.10)	11.62 (1.30)	11.53 (1.05)	11.60 (1.81)	8.62 (0.99)	12.66 (1.56)	
A1/2	9.41 (0.96)	9.57 (0.80)	12.47 (1.18)	12.15 (1.28)	13.04 (0.92)	9.65 (1.04)	13.89 (0.91)	
Ac								

The Ac stage is omitted for age estimation. Only teeth that have not fully developed are used to estimate the age of the individual. The median age at which the stage of calcification is visible and the standard deviation are shown in brackets.

RESULTS

The dental age related tables, derived from pivot tables, showed that there are differences in the developmental stages of the teeth in the left mandible for each ethnic group. Table 1 shows the various ages at which the calcification stages of the incisors, canine, premolars and molars of Tygerberg children are visible on Pantomographic radiographs. The median age at which the various stages of calcification of each tooth are visible is shown in years with the standard deviation in brackets. Table 2 shows the various ages at which the calcification stages of the incisors, canine, premolars and molars of the Indian children are visible on Pantomographic radiographs. The median age at which calcification is visible is shown in years with the standard deviation. Table 3 shows similar age related stages for the Nguni children. The median age for each stage and the standard deviation are shown. Table 4 shows the number of individuals per age group for each of the sample groups. Table 5 shows the standard abbreviation of developmental stages of teeth.

The MFH method of age estimation of the new Tygerberg sample resulted in 38.4% of the sample being estimated to within 1 year of the real age (Graph 1a). The *accuracy* of the MFH method is measured by the amount of scatter in relation to the trend line (Graph 1b).Regression analysis of the MFH method showed an R-value of 0.63 with a p-value of 1.6376×10^{-11}(Table 6).

Table 3: *Dental Age Related Table for Nguni Children (SD in years) (n = 236)*

	I 1	I 2	C	Pm1	Pm2	M1	M2	M3
Fi								
F								
Ci								8.50 (0.96)
Cco								9.64 (1.18)
Coc					5.94		5.94	10.91 (1.30)
Cr1/2				6.03 (0.12)	6.45 (0.64)		6.50 (0.67)	11.30 (1.47)
Cr3/4			6.12 (0.01)	6.57 (0.73)	7.32 (1.54)		6.94 (1.04)	11.93 (1.43)
Crc		6.12	6.35 (0.71)	7.72 (1.83)	8.07 (1.64)		7.87 (0.90)	12.54 (1.02)
Ri	6.12 (0.01)	6.03 (0.12)	6,74 (0.40)	7.80 (1.30)	8.46 (0.92)		10.03 (1.65)	12.76 (0.98)
Cli							9.45 (1.31)	13.82 (1.55)
R1/4	6.14 (0.40)	6.52 (0.66)	8.44 (1.25)	8.97 (0.81)	9.93 (0.96)		10.27 (0.89)	14.45 (0.97)
R1/2	6.79 (0.87)	7.01 (0.97)	9.29 (0.58)	9.82 (0.82)	10.48 (1.18)	6.22 (0.34)	11.43 (1.39)	15.64 (0.91)
R3/4	7.24 (1.26)	6.94 (0.44)	10.71 (1.31)	10.50 (1.11)	11.22 (1.21)	7.21 (0.95)	12.24 (0.87)	15.78
Rc	8.91 (1.14)	9.07 (0.86)	11.73 (1.42)	11.65 (1.32)	12.33 (1.29)	8.35 (0.97)	12.99 (1.29)	
A1/2	8.98 (1.01)	10.13 (1.21)	12.49 (1.26)	12.34 (1.07)	13.06 (1.37)	9.60 (1.05)	13.72 (1.01)	
Ac								

The Ac stage is omitted for age estimation. Only teeth that have not fully developed are used to estimate the age of the individual. The median age at which the stage of calcification is visible and the standard deviation are shown in brackets.

Table 4: *The number of children in each age group*

Children Age Groups for Tygerberg, Indian & Nguni Samples

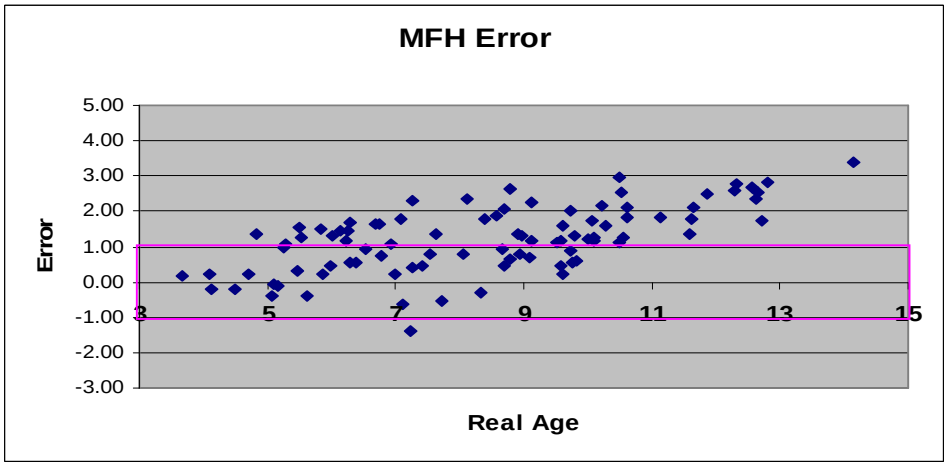
Age Group Years	**No. in Group**		
	Tygerberg	**Indian**	**Nguni**
3 to 4	10		
4 to 5	40		
5 to 6	70		2
6 to 7	98	2	7
7 to 8	115	5	6
8 to 9	133	20	13
9 to 10	110	37	22
10 to 11	89	39	26
11 to 12	128	42	36
12 to 13	74	33	47
13 to 14	54	28	26
14 to 15	30	20	27
15 to 16	41	4	15
16 to 17	14	4	9
Total	**1006**	**234**	**236**

Table 5: *The standard abbreviation of developmental stages of teeth*

Ci	Cusp initiation
Cco	Cusp coalescence
Coc	Cusp outline complete
Cr½	Crown half formed
Cr¾	Crown three quarters formed
Crc	Crown completely formed
Ri	Root initiation
Cli	Cleft initiation (molars only)
R¼	Root one quarter formed
R½	Root half formed
R¾	Root three quarters formed
Rc	Root complete
A½	Apex one half complete
Ac	Apex complete

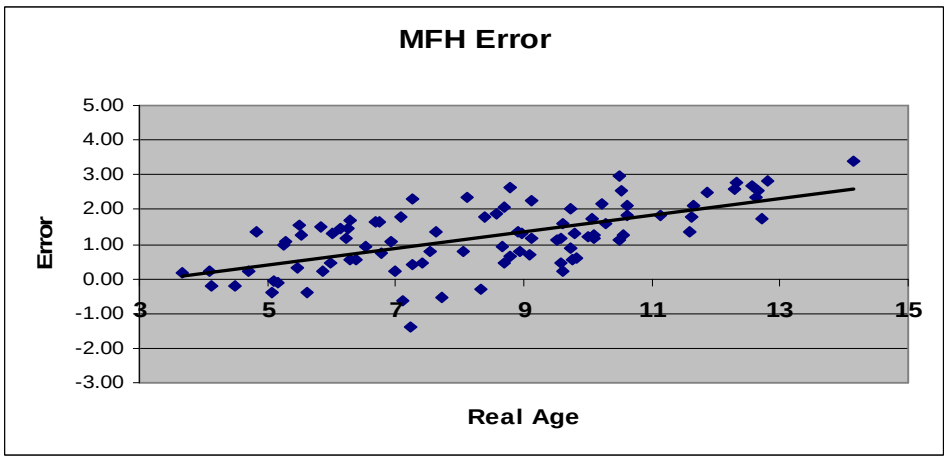
Moorrees, Fanning & Hunt (1963)

Graph 1a: *The age estimation error of the MFH method. Tygerberg (n = 91)*



The scale of the error is from -3.00 to 5.00. The *alignment* of the sample (Graph 1a) shows that 38.4 % of the sample is within 1 year of Real Age. The MFH method under-estimates the ages of the majority of the sample. [If the error is positive then the estimated age is less than the real age]

Graph 1b: *The age estimation error of the MFH method. Tygerberg (n = 91)*



The *accuracy* of the MFH method is measured by the amount of scatter in relation to the trend line (Graph 1b). The R-value (R = 0.633) indicates that the MFH method is strongly predictive. The regression correlation is significant ($p<0.05$)

***Table 6:**: Regression analysis of MFH method on the Tygerberg sample*

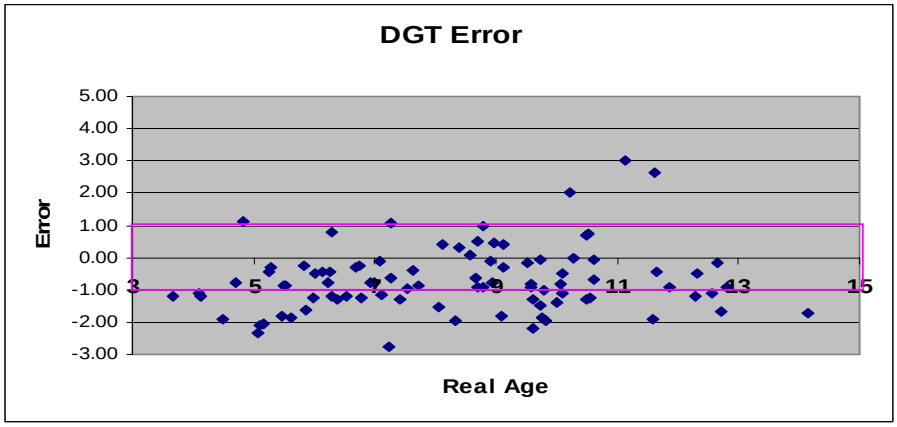
Regression Statistics	
R	0.633
R Square	0.401
Observations	91

ANOVA

	df	Significance F
Regression	1	1.63^{-11}

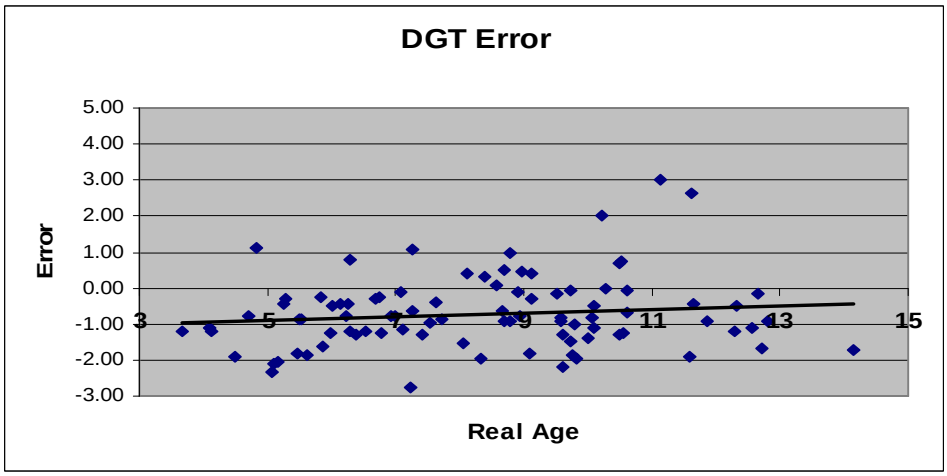
The DGT method of age estimation of the Tygerberg sample resulted in 53.8% of the sample being estimated to within 1 year of the real age (Graph 2a). The *accuracy* of the DGT method is measured by the amount of scatter in relation to the trend line (Graph 2b). Regression analysis of the DGT method showed an R-value of 0.91 with a p-value of 2.40 x 10^{-36} (Table 7).

***Graph 2a:** The age estimation error of the DGT method. Tygerberg (n = 91)*



The scale of the error is from -3.00 to 5.00.The *alignment* of the sample (Graph 2a) shows that 53.8 % of the sample is within 1 year of Real Age. The DGT method over-estimates the ages of the sample. [If the error is negative then the estimated age is greater than the real age]

***Graph 2b:** The age estimation error of the DGT method. Tygerberg (n = 91)*



The *accuracy* of the DGT method is measured by the amount of scatter in relation to the trend line (Graph 2b). The R-value (R = 0.913) indicates that the DGT method is strongly predictive. The regression correlation is significant ($p<0.05$)

Table 7: *Regression analysis of the DGT method on the Tygerberg sample*

Regression Statistics	
R	0.913
R Square	0.833
Observations	91

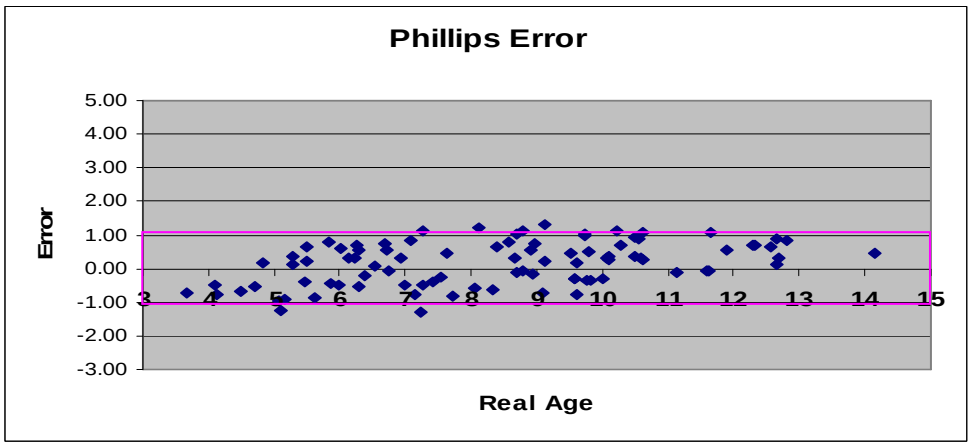
ANOVA

	df	Significance F
Regression	1	2.40^{-36}

The R correlation is significant ($p<0.05$) and strongly predictive. This method is more accurate than the MFH method, but over-estimates the ages of 46.8% of the Tygerberg sample.

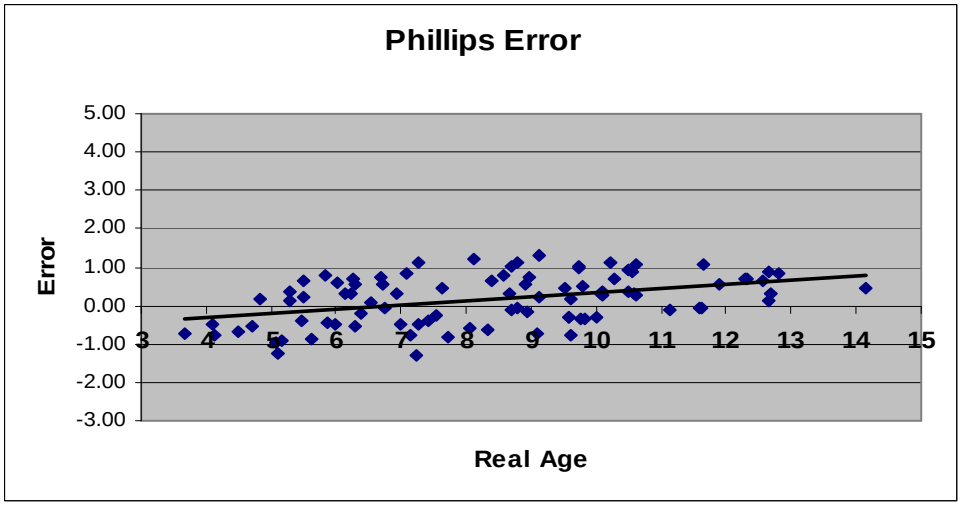
The Phillips Table 1 used for age estimation of the Tygerberg sample resulted in 88.4% of the sample being estimated to within 1 year of the real age (Graph 3a).
The *accuracy* of the Phillips method is measured by the amount of scatter in relation to the trend line (Graph 3b). Regression analysis of the Phillips Table 1 showed an R-value of 0.966 with a p-value of 3.18×10^{-54} (Table 8).

Graph 3a: *The age estimation error of the Phillips Table 1. Tygerberg (n = 91)*



The scale of the error is from -3.00 to 5.00. *The alignment* of the sample shows that 88.4 % of the sample is within 1 year of Real Age.

Graph 3b: *The age estimation error of the Phillips Table 1. Tygerberg (n = 91)*



The *accuracy* of the Phillips method is measured by the amount of scatter in relation to the trend line (Graph 3b). The R-value (R = 0.966) indicates that the Phillips method is strongly predictive. The R correlation is significant ($p<0.05$)

Table 8: *Regression analysis of the Phillips Table 1 on the Tygerberg sample*

Regression Statistics	
R	0.966
R Square	0.934
Observations	91

ANOVA

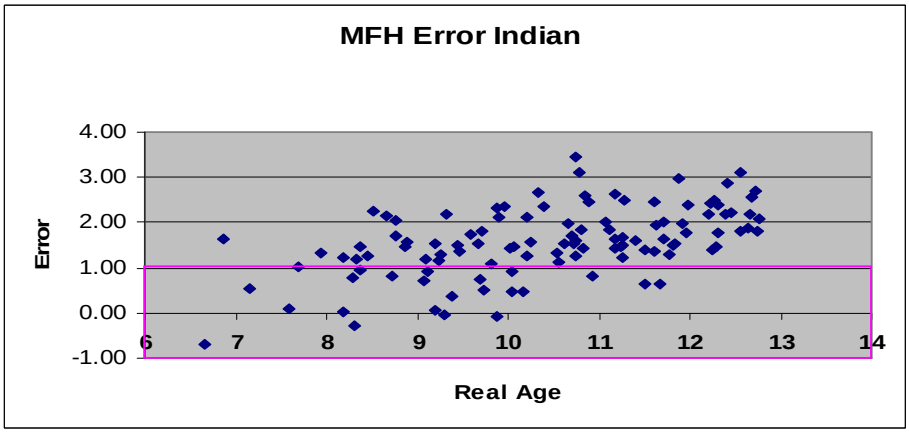
	df	Significance F
Regression	1	3.18^{-54}

The Phillips method is more accurate than the MFH and the DGT methods for ageing Tygerberg children.

The MFH method of age estimation of the Indian sample resulted in 19.6% of the sample being estimated to within 1 year of the real age (Graph 4a).

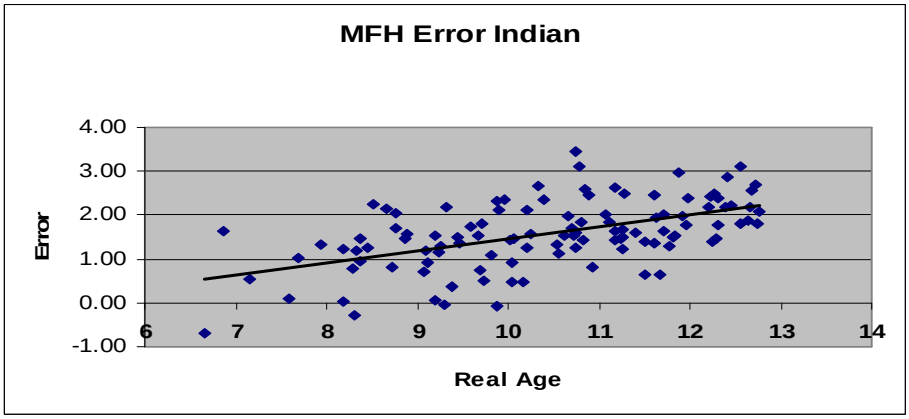
The *accuracy* of the MFH method is measured by the amount of scatter in relation to the trend line (Graph 4b). Regression analysis of the MFH method showed an R-value of 0.54 with a p-value of 7.704×10^{-10} (Table 4).

Graph 4a: *The age estimation error of the MFH method. Indian (n = 112)*



The scale of the error is from -1.00 to 4.00. The *alignment* of the sample (Graph 4a) shows that 19.6 % of the sample is within 1 year of Real Age. The MFH method under-estimates the ages of the majority of the sample.

Graph 4b: *The age estimation error of the MFH method. Indian (n = 112)*



The *accuracy* of the MFH method is measured by the amount of scatter in relation to the trend line (Graph 4b). The R-value (R = 0.540) indicates that the MFH method is predictive. The regression correlation is significant ($p<0.05$)

Table 9: *Regression analysis of the MFH method on the Indian sample*

Regression Statistics	
R	0.540
R Square	0.292
Observations	112

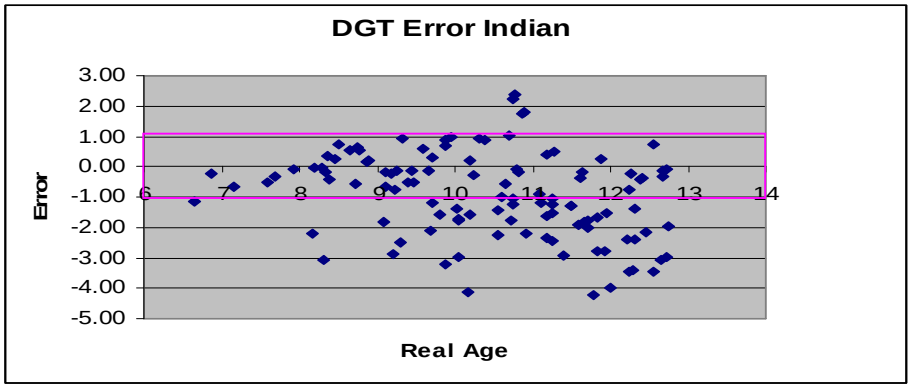
ANOVA

	df	Significance F
Regression	1	7.704^{-10}

The R correlation is significant ($p<0.05$) and predictive, but the MFH method under-estimates the ages of 80.4% of the Indian sample.

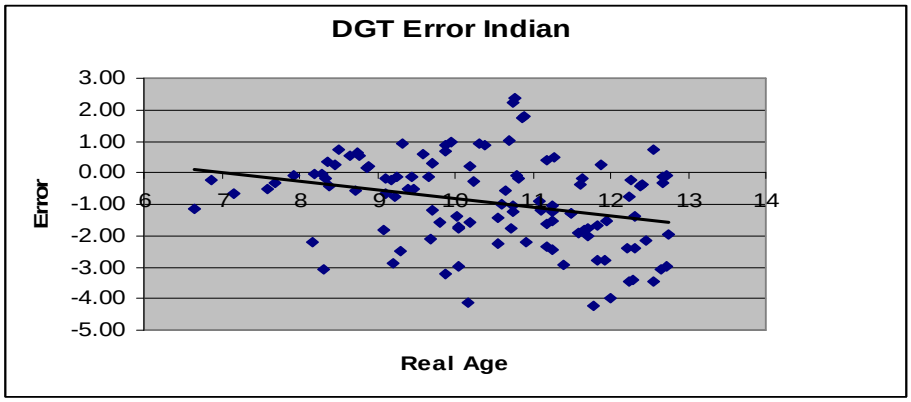
The DGT method of age estimation of the Indian sample resulted in 46.4% of the sample being estimated to within 1 year of the real age (Graph 5a). The *accuracy* of the DGT method is measured by the amount of scatter in relation to the trend line (Graph 5b). Regression analysis of the DGT method showed an R-value of 0.306 with a p-value of 0.001022 (Table 10).

Graph 5a: *The age estimation error of the DGT method. Indian (n = 112)*



The scale of the error is from -5.00 to 3.00.*The alignment* of the sample (Graph 5a) shows that 46.4 % of the sample is within 1 year of Real Age. The DGT method over-estimates the ages of the majority of the sample. [If the error is negative then the estimated age is greater than the real age]

Graph 5b: *The age estimation error of the DGT method. Indian (n = 112)*



The *accuracy* of the DGT method is measured by the amount of scatter in relation to the trend line (Graph 5b). The R-value (R = 0.306) indicates that the DGT method is predictive, but there is a significant amount of scatter around the trend line. The regression correlation is significant ($p<0.05$)

Table 10: *Regression analysis of the DGT method on the Indian sample*

Regression Statistics	
R	0.306
R Square	0.094
Observations	112

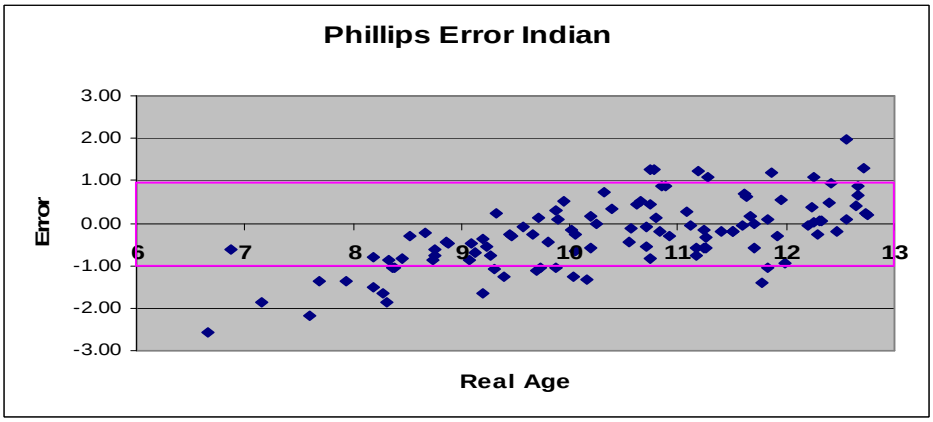
ANOVA

	df	Significance F
Regression	1	0.001022684

The regression correlation is significant ($p<0.05$) for the DGT method. The method overestimated the ages of 53.6% of the Indian sample.

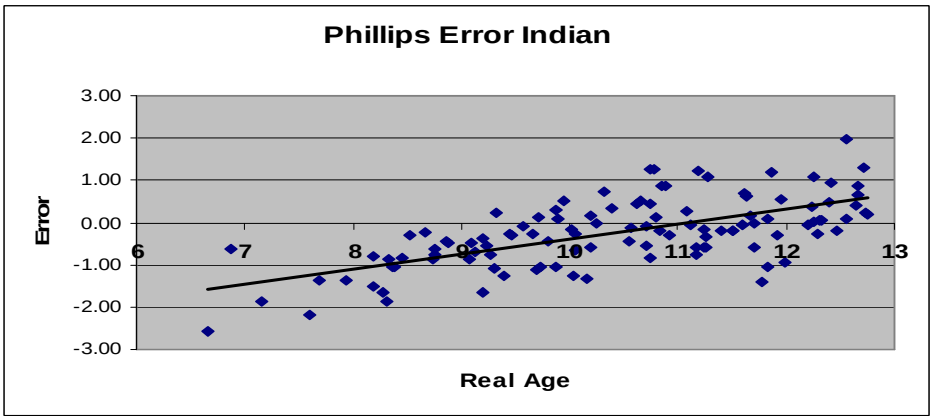
The Phillips Table 2 used for age estimation of the Indian sample resulted in 75% of the sample being estimated to within 1 year of the real age (Graph 6a). The *accuracy* of the Phillips method is measured by the amount of scatter in relation to the trend line (Graph 6b). Regression analysis of the Phillips Table 2 showed an R-value of 0.65 with a p-value of 8.22×10^{-15} (Table 11).

Graph 6a: *The age estimation error of the Phillips Table 2. Indian (n = 112)*



The scale of the error is from -3.00 to 3.00. *The alignment* of the sample shows that 75 % of the sample is within 1 year of Real Age.

Graph 6b: *The age estimation error of the Phillips Table 2. Indian (n = 112)*



The *accuracy* of the Phillips method is measured by the amount of scatter in relation to the trend line (Graph 6b). The R-value (R = 0.651) indicates that the Phillips method is strongly predictive. The R correlation is significant ($p<0.05$)

Table 11: *Regression analysis of Phillips Table 2 on the Indian sample*

Regression Statistics	
R	0.651
R Square	0.423
Observations	112

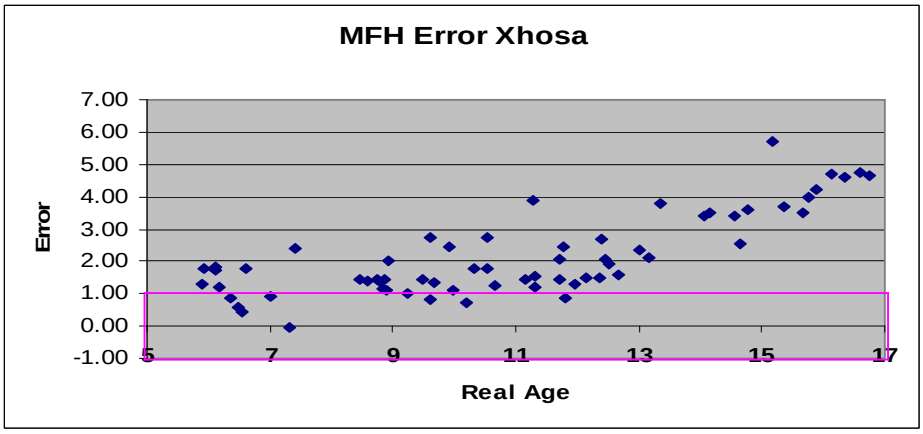
ANOVA

	df	*Significance F*
Regression	1	8.22^{-15}

The Phillips method is more accurate than the MFH and the DGT methods for ageing Indian children.

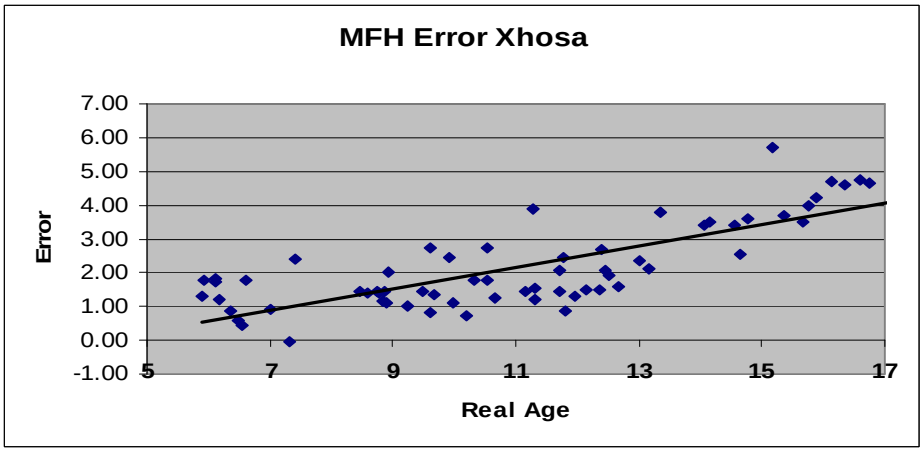
The MFH method of age estimation of the Xhosa sample resulted in 13.8% of the sample being estimated to within 1 year of the real age (Graph 7a). The accuracy of the MFH method is measured by the amount of scatter in relation to the trend line (Graph 7b). Regression analysis of the MFH method showed an R-value of 0.784 with a p-value of 1.069×10^{-14} (Table 12).

Graph 7a: *The age estimation error of the MFH method. Xhosa (n = 65)*



The scale of the error is from -1.00 to 7.00. The *alignment* of the sample (Graph 7a) shows that 13.8 % of the sample is within 1 year of Real Age. The MFH method under-estimates the ages of the majority of the sample.

Graph 7b: *The age estimation error of the MFH method. Xhosa (n = 65)*



The *accuracy* of the MFH method is measured by the amount of scatter in relation to the trend line (Graph 7b). The R-value (R = 0.784) indicates that the MFH method is strongly predictive. The regression correlation is significant ($p<0.05$)

Table 12: *Regression analysis of the MFH method on the Xhosa sample*

Regression Statistics	
R	0.784
R Square	0.615
Observations	65

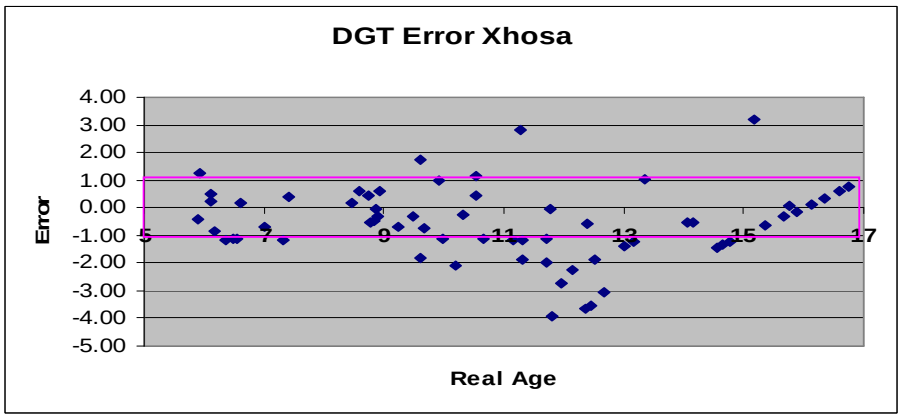
ANOVA

	df	Significance F
Regression	1	1.069^{-14}

The R correlation is significant (p<0.05) and predictive, but the MFH method under-estimates the ages of 86.2% of the Xhosa sample.

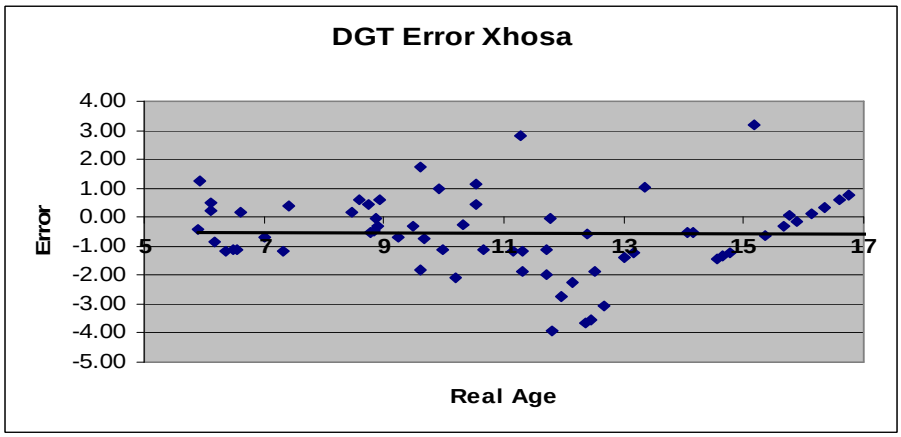
The DGT method of age estimation of the Xhosa sample resulted in 49.2% of the sample being estimated to within 1 year of the real age (Graph 8a). The *accuracy* of the DGT method is measured by the amount of scatter in relation to the trend line (Graph 8b). Regression analysis of the DGT method showed an R-value of 0.013 with a p-value of 0.912 (Table 13).

Graph 8a: *The age estimation error of the DGT method. Xhosa (n = 62)*



The scale of the error is from -5.00 to 4.00.*The alignment* of the sample (Graph 8a) shows that 49.2 % of the sample is within 1 year of Real Age. The DGT method over-estimates the ages of the majority of the sample. [If the error is negative then the estimated age is greater than the real age]

Graph 8b: *The age estimation error of the DGT method. Xhosa (n = 62)*



The *accuracy* of the DGT method is measured by the amount of scatter in relation to the trend line (Graph 8b). The R-value (R = 0.014) indicates that the DGT method is not predictive because there is a significant amount of scatter around the trend line even though this line is parallel to the X-axis. The regression correlation is not significant (p=0.912)

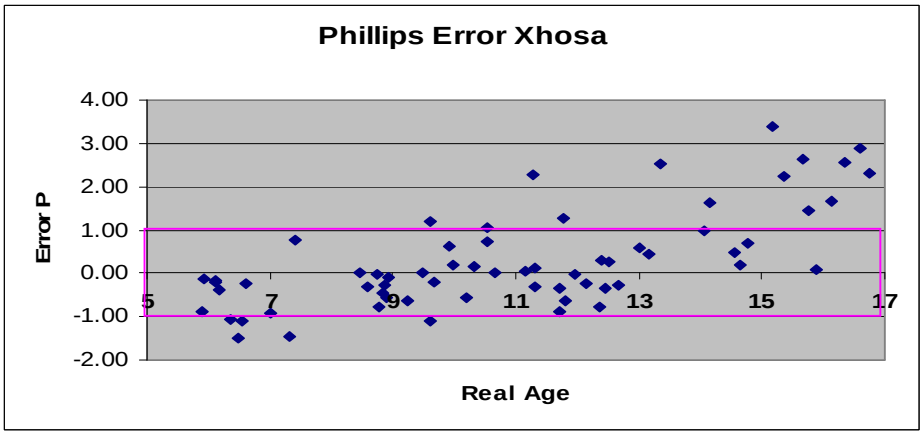
Table 13: *Regression analysis of the DGT method on the Xhosa sample*

Regression Statistics	
R	0.014
R Square	0.0001
Observations	65

ANOVA		
	df	Significance F
Regression	1	0.912

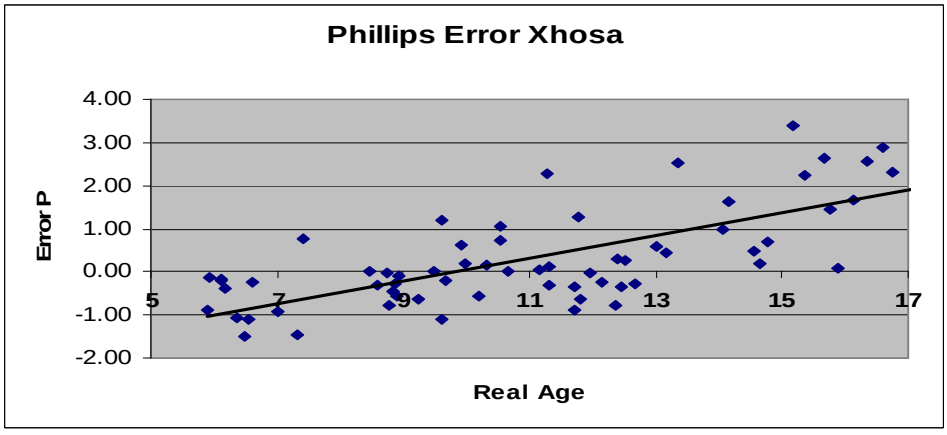
The DGT method is inaccurate for age estimation of this Xhosa sample.
The Phillips Table used for age estimation of the Xhosa sample resulted in 69.2% of the sample being estimated to within 1 year of the real age (Graph 9a). The *accuracy* of the Phillips method is measured by the amount of scatter in relation to the trend line (Graph 9b). Regression analysis of the Phillips Table 3 showed an R-value of 0.71 with a p-value of 2.10×10^{-11} (Table 14).

Graph 9a: *The age estimation error of the Phillips Table 3. Xhosa (n = 62)*



The scale of the error is from -2.00 to 4.00. The *alignment* of the sample shows that 69.2% of the sample is within 1 year of Real Age.

Graph 9b: *The age estimation error of the Phillips Table 3. Xhosa (n = 62)*



The *accuracy* of the Phillips method is measured by the amount of scatter in relation to the trend line (Graph 9b). The R-value (R = 0.716) indicates that the Phillips method is strongly predictive. The R correlation is significant ($p<0.05$)

Table 13: *The Regression analysis of Phillips Table 3 on Xhosa sample*

Regression Statistics	
R	0.716
R Square	0.512
Observations	65

ANOVA

	Significance F
Regression	2.10552E-11

Table 14: *The percentages of the Tygerberg, Indian & Xhosa samples estimated to within 1 year of the chronological age using the methods of MFH, DGT and Phillips*

	Tygerberg	Indian	Xhosa
MFH	38.4	19.6	13.8
DGT	53.8	46.4	49.2
Phillips	88.4	75.0	69.2

Table 15: *The regression correlation for the MFH, DGT & Phillips methods*

	Tygerberg	Indian	Xhosa
MFH	R = 0.633	R = 0.540	R = 0.784
DGT	R = 0.913	R = 0.306	R = 0.014
Phillips	R = 0.966	R = 0.651	R = 0.716

The Phillips method is more accurate for the age estimation of Xhosa children than the MFH and DGT methods.

The age estimation errors for the Tygerberg sample using the MFH, DGT and the Phillips Table 1 resulted in 38.4%, 53.8% and 88.4% of the sample being within 1 year of the chronological ages of the individuals respectively (Table 14). The regression analysis of the estimated ages of the Tygerberg sample showed that the r-value of 0.966 and the p-value of $3.18x10^{-54}$ indicate that the Phillips Table 1 for White and Coloured children is more accurate than the methods of MFH and DGT (Table 15). The age estimation errors for the Indian sample using the MFH, DGT and the Phillips Table 2 resulted in 19.6%, 46.4% and 75% of the sample being within 1 year of the chronological ages of the individuals respectively (Table 14). The regression analysis of the estimated ages of the Indian sample showed that the r-value of 0.651 and the p-value of $8.22x10^{-15}$ indicate that the Phillips Table 2 for Indian children is more accurate than the methods of MFH and DGT (Table 15). The age estimation errors for the Xhosa sample using the MFH, DGT and the Phillips Table methods resulted in 13.8%, 49.2% and 69.2% of the sample being within 1 year of the chronological ages of the individuals respectively (Table 14). The regression analysis of the estimated ages of the Xhosa sample showed that the r-value of 0.716 and the p-value of $2.106x10^{-11}$ indicate that the Phillips Table 3 for Xhosa children is more accurate than to the methods of MFH and DGT (Table 15).

DISCUSSION

The comparison of the developmental stages of each tooth from the Tygerberg, Indian and the Nguni samples showed that the Tygerberg sample, which consisted of White and Coloured children, are slightly ahead of the Indian and Nguni children in the calcification of the apices of the incisors, canine, premolars and 1st molar. The calcification of the root apex in the 2nd and 3rd molars shows a reversal in the developmental ages. The Indian and Black children are slightly ahead of the Tygerberg children. The differences in the calcification stages of the teeth in the

sample groups is marginally different and of importance when dealing with age prediction in living children who are undergoing orthodontic treatment or in clinical evaluation of relating their skeletal maturity to their dental development. If, however, one is estimating the age of skeletal remains of children, it would appear that the slight differences in the ages at the various developmental stages of the teeth are not as critical as originally believed. In the dental age related tables (Tables 1, 2 & 3) the sex difference has been omitted and generic tables for combined sexes were derived. A study by Phillips[18] has shown that there are slight differences in the ages of the calcification stages of the teeth of boys and girls; this varies by a few months and is not significant enough to influence the age estimation of skeletal remains.

It is often impossible to decide if skeletal remains of a child are either male of female and before secondary sex characteristics develop; it is also not possible to determine the ethnic origin of the skeletal remains of young individuals. It is therefore proposed that the tables for Tygerberg children be used if the ethnicity is known to be of White or Coloured origin. Similarly the Indian and Nguni tables are used if the individual is of Indian or Black origin.

The 'Ac' stage in the dental age related tables was omitted as no age can be assigned to age estimation when complete maturity of a tooth has been reached, because the individual has passed this transition by an unknown amount of time, as recommended by Smith (1991).[5] Age estimation is therefore established by assessing the developing teeth that have not attained root apex closure derived from the left mandible and calculating the mean age using only these teeth.

The MFH method consistently under-estimated the ages of the South African children. The performance of the MFH method for the White and Coloured children was poor as it only estimated the ages of 38% of the sample to within 1 year of the chronological age. The MFH method performed very poorly for the Indian and Xhosa children. The DGT method over-estimated the ages of the samples. The performance of the DGT method was relatively constant for all three samples, estimating the ages to within 1 year in approximately 50% in all cases. The Phillips Tables for White and Coloured, Indian and African (Nguni) children was found to be more accurate than the MFH and DGT methods when estimating the ages of South African children.

The Xhosa children came from a poor socio-economic area and age estimation of these children using the age related stages of tooth calcification derived mainly from Zulu children (Phillips 3), resulted in 69.2% of the sample estimated to within 1 year of the real age. This suggests that the socio-economic environment of a child may play a role in the calcification of the permanent teeth and influence the radiographic images of these teeth for aging purposes. This needs to be investigated.

CONCLUSION

The dental age related tables that have been derived for White/Coloured, Indian and Black children of South African origin show that there are differences in the ages at which tooth calcification takes place for the teeth of the left mandibular quadrant. These differences in the ages at which the various stages of tooth development are visualized for each of the sample groups varies enough to warrant specific dental age related tables for children of different ethnic origins. In the forensic analysis of the skeletal remains of South African children these tables will be beneficial in the age estimation of individuals. If the ethnic origin of the individual is known the use of these tables would result in a more accurate age estimation compared to Moorrees, Fanning and Hunt (1963) or Demirjian, Goldstein and Tanner (1973).

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