A LONGITUDINAL STUDY OF SKELETAL AND DENTAL MATURATION IN SUBJECTS WITH VARIOUS TYPES OF DENTAL OCCLUSION

by

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DEDICATION

To the author's parents, whose unselfishness and guidance made his education possible.

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INTRODUCTION

Maturity indicators have been described as features of a body part which, because they tend to recur regularly and in a definite order, mark the progress of a child towards maturity. The concept of the maturity indicator, which developed from studies of bone growth and anatomy, has been demonstrated to be of value in the assessment of the physical status and the biological age of children. The purpose of this longitudinal study is to observe and to compare the dental and skeletal maturation of children with different types of dental occlusions. The teeth and bones of the hand and wrist were used as maturity indicators.

A knowledge of the relationship between dental development, skeletal development, and types of dental occlusion could be of predictive, practical, and theoretical value in orthodontics. The beginning of orthodontic treatment should depend more upon the stage of dental and skeletal maturation than on chronological age. Detection of discrepancies between dental age and skeletal age may be of help in the early recognition and diagnosis of developing disturbances of the dentition.

Thirty-eight children, twenty females and eighteen males, were selected for this investigation. The children were divided into control and experimental groups and were studied at approximately eight and twelve years of age. The necessary classifications and evaluations

were based upon lateral cephalograms, right and left oblique cephalograms, radiographs of the left wrist and hand, and plaster record casts of the dentition. The results of this study were subjected to statistical analysis.

REVIEW OF THE LITERATURE

Interest in the scientific study of human growth has created a need for better methods of observing and recording the various processes of development and their relationship to the individual. Human development is both quantitative and qualitative in nature. The quantitative attribute of growth and its association with changes in body dimensions is quite familiar to most parents and research workers. However, the quantitative nature of these phenomena are of little value in appraising the true developmental status of the child at a specific moment in time. Such difficulties have lead to a search for reliable qualitative methods of evaluating maturation as an indicator of a child's developmental status. Through the use of X-rays and the resultant radiographic pictures, it is possible to observe the ossification processes of the living skeleton. Such an approach has lead to the concept of the maturity indicator, which developed from the intensive study of bone growth and anatomy. Skeletal maturity evaluations are based upon the identification of certain qualitative changes in various stages of development. In order to be classified as a maturity indicator the stages or features assessed must be constant in order of appearance and be universal in occurrence. However, the time intervals between the stages may be variable from individual to individual. A maturity indicator may then be defined as " . . . an identifiable point or stage in the development of a structure or

a function which occupies a fixed point in a series." (1).

The first published work to present a rating technique for evaluation of skeletal development and to show the predictability of several types of skeletal measurements was presented by Flory (2), in 1936. The appraisal of the osseous development of the hand and wrist as a reliable index of skeletal maturity has been well established by the work of Greulich and Pyle (3). Moed, Wright, and Vandergrift (4) have reaffirmed the reliability and reproducibility of such skeletal assessments.

In recent years attempts have been made to broaden the concept of the maturity indicator to include any clearly identifiable stage of development which conforms to the necessary requirements. Various body tissues have been studied, among these the human dentition.

Early work involving tooth formation was cross-sectional in nature and performed without regard for the use of such data as an index of the individual's total development. Most of these reports were concerned with the correlation of certain limited stages of tooth development, such as initiation of calcification, with chronological age; rather than the complete evolution of the dentition and its relevance to physiological maturity (5, 6, 7, 8). Kronfeld (9), in 1935, expanded the interpretations of his earlier work with Logan (8) and established mean chronological ages at which the initiation and the completion of crown formation of the mandibular first permanent molar might be expected. It is interesting to note that in his reference to Aoki (10), he speculates that the onset of calcification of the mandibular first permanent molar was rather constant all over the world.

Thus we have one of the first indications that the calcification of the teeth might be used as an index of maturation.

For years the attempt to establish a dental age, which would be of significant value as an index of maturation, was confined to the use of eruption tables. This approach has been discredited numerous times by many investigators, eruption being considered a fleeting event which is extremely difficult to quantitate (11, 12, 13). Strott and his co-workers (1) were of the opinion that owing to the wide variability of eruption times such age equivalents may be taken as only a crude representation of a developmental process.

Although most of the work regarding the chronology of the dentition has been confined to the study of a few well defined developmental stages, some charts relating to the gross time-magnitude relationship of tooth formation have been presented (14, 15, 16, 17, 18). In 1940, Schour and Massler (19) reported their studies of tooth development and the growth patterns of the human teeth. They stated that with the use of radiographs it was possible not only to estimate more accurately the dental age of the subject, but that the quantity of dentin formation in the crowns and roots of the teeth was an index of physiological age.

The use of dental maturity indicators, based upon the calcification of the tooth germ and the characteristic stages of tooth formation, as an index of physiological maturation has been reasonably established (13, 20, 21, 22, 23, 24, 25, 26, 27). Nolla (28) conducted a radiographic study of the development of dentition by

means of serial oral radiographs of twenty-five boys and twenty-five girls. From his study, Nolla devised a technique for the detailed assessment of the development of the permanent dentition as revealed by radiographs. He constructed tables and norms which would permit the individual interpretation of differences in dental growth by the age-unit method. His contribution to the use of dental calcification as a maturity indicator is significant and the most complete work of its kind to date. The dental age assessments used in this study were accomplished by the use of Nolla's standards.

Attempts have been made to correlate skeletal and dental development with other factors. For years researchers have investigated skeletal and dental maturation as related to chronological age and to body growth in general (29, 30, 31, 32, 33). Other workers have studied the effects of endocrine and nutritional disturbances upon bones and teeth (19, 34, 35, 36, 37). Howard (38, 39), Osgood (40), and Salzman (41) have emphasized the importance of evaluating the physiological status of the bone and the development of the dentition as criteria for initiating orthodontic treatment. Downs (42) and Moorrees (43) have attempted to quantitate developmental factors which might contribute to disharmonies in skeletal and dental growth. In 1961, Lauterstein (44) conducted a cross-sectional investigation of dental age and skeletal age. He urged that a longitudinal study of these factors and of dento-facial development be carried out. Lauterstein stressed that such an effort could result in a reliable and clinically useful atlas for predicting dento-facial patterns of development. Dental texts and journals are replete with reports of

such investigations, but nowhere in the literature is there a report of studies correlating the longitudinal development of these two maturity indicators with resultant types of dental occlusion. It is to be remembered that a presentation of measurement values alone is meaningless. Only when such measurements are seen in relation to other standards of reference do they become meaningful. With these thoughts in mind the present investigation was undertaken.

METHODS AND MATERIALS

Subjects were selected after an examination of the lateral cephalometric radiographs of children enrolled in the University of Michigan Elementary School Growth study. The Growth Study is composed of Ann Arbor, Michigan elementary school children. The sample selected is composed of white children. Sample selection was based upon the availability of the following records:

1. Lateral cephalometric radiographs taken in occlusion at approximately twelve years of age.
2. Right and left oblique cephalometric radiographs at eight and twelve years of age, plus or minus six months. When these records were not available the seven and eleven year records were used.
3. Radiographs of the left hand and wrist at ages which correspond to the ages indicated for the oblique cephalograms.
4. Plaster record casts of the dentition obtained at approximately twelve years of age and one additional set of casts appropriate for a mixed dentition analysis.

Whenever available, lateral cephalometric radiographs and record casts of the same patient, obtained at ages later than twelve years were also studied to confirm the reliability of the twelve year records.

Lateral cephalometric radiographs nearest to twelve years of age were examined. To be included in the study all subjects were re-

quired to have Downs' A and B points fall within plus or minus one standard deviation of the mean, anteroposteriorly, for comparable age standards on the University of Michigan Cephalometric Template Analysis (45).* Figure 1 illustrates the Template Analysis and the various cephalometric points used for the other angular measurements. The age standards within which the subjects' A and B points fell on the template were not required to correspond to the means and standard deviation for the chronologic age of the subject, provided that both points were within plus or minus one standard deviation of the mean for the same age standard.

Subjects were eliminated from the study when records showed evidence of dental mutilation.

In addition to the University of Michigan Template Analysis for skeletal relations of A and B points, SNA, SNB, and NAP angular measurements, as described by Reidel (46) and Downs (47), were made on the tracings of the twelve year cephalometric records. Similarly, the relation of A point to B point was recorded for each subject by the Burlington method (48). The results of these measurements are recorded in Tables 1 and 2. A total of six skeletal measurements were made for each subject. All subjects selected for this study were considered to possess skeletal relationships within the range of "normal."

The sample selected on the basis of skeletal balance and the availability of the necessary records, consisted of twenty females and eighteen males. Classification of the thirty-eight subjects into

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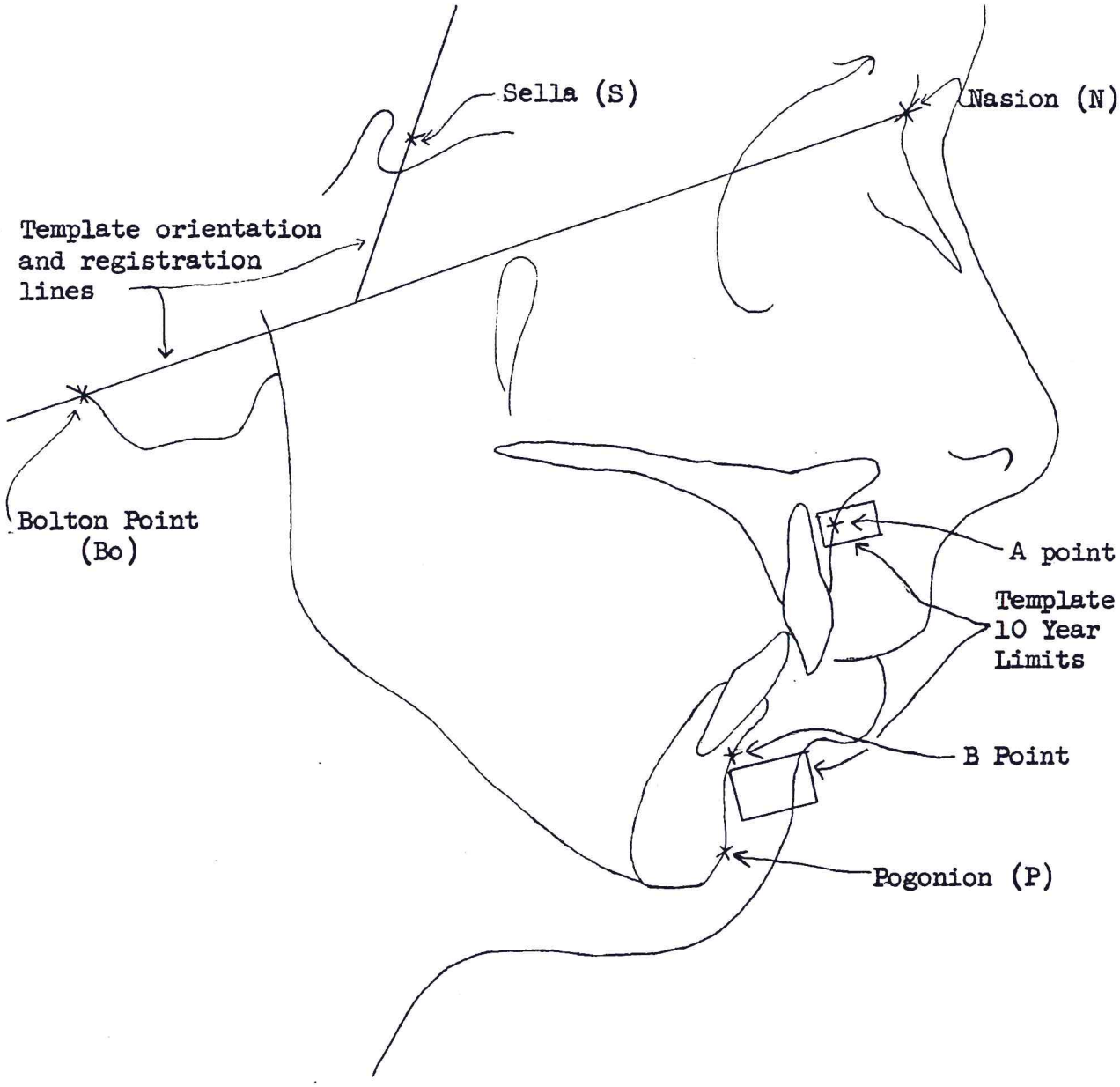

Fig. 1.--The rectangles adjacent to the maxillary and mandibular incisor teeth represents the plus or minus one standard deviation limits for A and B points for a specific chronologic age. The subject illustrated here would not be included in the study since B point does not fall within the required limits.

experimental and control groups was based upon the dental characteristics of each subject. These characteristics were determined by examination of the record casts taken at approximately twelve years of age. A modification of the code method employed at the Burlington Center for Orthodontic Research (48) to identify and record various dental characteristics of the occlusion was used as follows:

Code I Antero-posterior denture relation of upper permanent cuspid to lower permanent cuspid and upper first permanent molar, to lower first permanent molar.

N - Dental neutrocclusion.

D - Dental distocclusion, half cusp displacement.

D+ - Dental distocclusion, full cusp displacement.

M - Dental mesiocclusion, half cusp displacement.

M+ - Dental mesiocclusion, full cusp displacement.

U - Unilateral.

Code II position of the teeth.

P1 - Anterior cross bite.

P2 - Posterior cross bite with maxilla to the lingual.

P3 - Upper incisor overjet to lower incisor, exceeding 4 mm.

P4 - Overbite exceeding 1/2 the lower incisor crown.

P5 - Openbite greater than 1 mm.

P6 - Open contacts in upper permanent teeth exceeding 3 mm.

P7 - Open contacts in lower permanent teeth exceeding 3 mm.

P8 - Midline diastema in upper arch exceeding 2 mm.

P9 - Crowding out of position of one or more upper teeth where 3 mm or more space is required for correction.

P10 - Crowding out of position of one or more lower teeth where 2 mm or more space is required for correction.

With the exception of Code I-N, neutrocclusion, subjects whose record casts indicated that one or more of the Code I or Code II characteristics were present, were placed in the experimental group. Dental neutrocclusion and the absence of all P characteristics were required for all subjects included in the control group.

The control group consisted of six females and four males. The experimental group consisted of fourteen females and fourteen males. The chronological age of the subjects in the control and experimental groups at the time of the skeletal and dental classifications are presented in Tables 3 and 4.

Two assessments of dental ages were made for each subject. Right or left oblique cephalograms obtained approximately four years apart were used for these assessments. The chronologic age of each individual at the time the oblique cephalometric radiographs were taken is recorded in Tables 5 and 6. The dental age assessments were made by a modification of the technique suggested by Nolla (28). This modification consisted of reducing the number of teeth evaluated to eight; the right and left mandibular first bicuspid, second bicuspid, first molar, and second molar. The alteration was necessary since in the

oblique cephalometric radiographs only the images of the mandibular posterior teeth were recorded clearly enough for such an evaluation.

Each evaluation of dental age was repeated a second time by the same investigator with a minimum of twenty-four hours between assessments. An error study was then conducted to estimate the methodological error and to determine its effect on the experimental results. These findings are recorded in Tables 7 and 8.

Two skeletal age evaluations were made for each subject from radiographic films of the left hand and wrist at ages which corresponded to the oblique cephalometric radiographs (Tables 5 and 6). The bone age assessments of each bone used to obtain the skeletal age of the hand and wrist were made according to the standards of Greulich and Pyle (3). To expedite the bone assessments of the films, the number of bones evaluated was reduced by omitting some bones which usually reach the same skeletal maturity levels simultaneously. It is considered that the use of the following maturity indicators will produce an accurate assessent of skeletal age: Distal end of the radius, distal end of the ulna, capitate, hamate, triquetral, lunate, scaphoid, I and II metacarpal, IV and V proximal phalanx, II distal phalanx, and adductor sesamoid of the thumb.

To determine the methodological error involved in the skeletal age determinations, one -fourth of the assessments were repeated with a minimum of twenty-four hours between evaluations for ten children. These findings are recorded in Tables 9 and 10.

TABLE 1

SKELETAL CHARACTERISTICS OF CONTROL GROUP

Female							Male						
Code #	MA	SNA	SNB	ANB	NAP	BA	Code #	MA	SNA	SNB	ANB	NAP	BA
111	+	+	+	-	+	-	203	+	+	+	+	-	+
112	+	-	-	+	+	-	210	+	+	+	+	+	+
113	+	+	+	+	+	-	212	+	+	+	+	+	-
118	+	+	+	+	+	+	217	+	+	+	+	+	-
119	+	+	+	+	+	+							
124	+	+	+	+	+	-							

TABLE 2

SKELETAL CHARACTERISTICS OF EXPERIMENTAL GROUP

Female							Male						
Code #	MA	SNA	SNB	ANB	NAP	BA	Code #	MA	SNA	SNB	ANB	NAP	BA
101	+	+	+	+	+	-	201	+	+	+	+	+	+
102	+	-	-	+	+	-	202	+	+	+	+	+	-
103	+	-	-	+	+	-	204	+	+	+	+	+	-
104	+	+	+	+	+	+	206	+	-	-	+	+	+
105	+	+	-	+	+	+	207	+	+	+	+	-	-
107	+	+	+	-	+	+	208	+	+	+	+	+	-
108	+	+	+	+	+	-	209	+	+	+	+	+	-
109	+	+	-	+	+	+	211	+	+	+	+	+	+
110	+	+	+	+	+	+	213	+	+	+	+	+	-
114	+	-	-	+	+	-	214	+	+	+	+	-	-
115	+	+	+	+	+	-	215	+	+	+	+	+	-
117	+	+	+	+	+	+	216	+	+	+	+	+	+
121	+	+	+	+	+	-	218	+	+	+	+	+	-
123	+	+	+	+	+	+	219	+	-	+	+	+	-

\+ = measurement within + or - one S.D. of the mean
\- = measurement outside of + or - one S.D. of the mean
MA = Michigan Template Analysis
BA = Burlington Analysis

TABLE 3

CONTROL GROUP
(Age at time of skeletal and dental classification)

FEMALES			MALES		
	Age in mons.			Age in mons.	
Code#	Ceph.	Casts	Code#	Ceph.	Casts
111	138	138	203	144	144
112	144	144	210	143	143
113	150	149	212	151	150
118	150	150	217	145	145
119	147	148			
124	142	154			

TABLE 4

EXPERIMENTAL GROUP
(Age at time of skeletal and dental classification)

FEMALES			MALES		
	Age in mons.			Age in mons.	
Code#	Ceph.	Casts	Code#	Ceph.	Casts
101	139	139	201	144	139
102	150	150	202	144	144
103	144	144	204	152	152
104	143	132	206	144	145
105	137	137	207	145	145
107	138	138	208	144	144
108	151	151	209	143	143
109	139	139	211	145	146
110	144	144	213	144	144
114	137	137	214	139	139
115	147	147	215	143	144
117	139	138	216	151	151
121	144	144	218	138	138
123	149	132	219	143	143

TABLE 5

CONTROL GROUP
(Age in months at time oblique cephalograms were taken)

FIRST AGE GROUP				SECOND AGE GROUP			
Females		Males		Females		Males	
Code#	Age	Code#	Age	Code#	Age	Code#	Age
111	91	203	96	111	138	203	144
112	96	210	95	112	144	210	143
113	84	212	103	113	132	212	151
118	96	217	95	118	150	217	145
119	97			119	147		
124	91			124	142		

TABLE 6

EXPERIMENTAL GROUP
(Age in months at time oblique cephalograms were taken)

FIRST AGE GROUP				SECOND AGE GROUP			
Females		Males		Females		Males	
Code#	Age	Code#	Age	Code#	Age	Code#	Age
101	90	201	91	101	139	201	138
102	92	202	97	102	141	202	144
103	96	204	84	103	144	204	132
104	95	206	96	104	143	206	144
105	89	207	96	105	137	207	145
107	90	208	84	107	138	208	133
108	103	209	89	108	151	209	131
109	91	211	97	109	138	211	145
110	84	213	96	110	132	213	144
114	90	214	91	114	137	214	139
115	96	215	95	115	147	215	143
117	90	216	84	117	139	216	132
121	96	218	91	121	144	218	138
123	99	219	96	123	149	219	143

STATISTICAL METHODS AND DATA

The statistical results of the error control study for dental age and skeletal age are presented in Tables 7, 8, 9 and 10.

A one tailed "t" test was conducted to ascertain if there was a greater error in making double determinations at chronological age twelve years, than chronological age eight years. The results of the test, based on the hypothesis that the terminal differences are equal to the beginning differences, are presented in Tables 11, 12, 13, and 14.

The experimental results concerning the skeletal age and dental age evaluations at a given chronological age for each subject are presented in Tables 15 and 16. Each dental age was evaluated twice and the average of these two evaluations was used to represent the dental age throughout the remainder of the experiment. Only one-fourth of the skeletal ages were evaluated twice and there was no statistically significant difference between the first and second evaluations (Tables 9 and 10); therefore, the initial evaluations were used to represent the skeletal age throughout the experiment.

The basic data, given in Tables 15 and 16, were separated according to beginning and terminal evaluations. These two categories were subdivided into control and experimental groups based upon the dental characteristics of each subject. The beginning and terminal evaluations were subjected to a student's "t" test. This test was con-

ducted to determine if the skeletal age was equivalent to the dental age in each of the separate groups. The test was based upon the hypothesis that the skeletal age minus the dental age equals zero. The results of these tests are represented in Tables 17, 18, 19, 20, 21, and 22.

During the time interval between the beginning evaluations and the terminal evaluations, the skeletal age increased more than the dental age. This trend was most noticeable in the experimental groups and was greatest in the experimental male group. Individual "t" tests were performed on each group, control and experimental, male and female, to determine if the skeletal age-dental age differences at the beginning of the experiment were significantly different from the skeletal age-dental age differences at the end of the experiment. The results are presented in Tables 23 and 24.

TABLE 7

ERROR CONTROL STUDY FOR DENTAL AGE EVALUATIONS
MALES

Code #	First Age Time 1	First Age Time 2	First Age T2-T1	First Age $(T2-T1)^2$	Second Age Time 1	Second Age Time 2	Second Age T2-T1	Second Age $(T2-T1)^2$
201	98.57	98.57	0.00		132.66	129.32	-3.34	
202	91.12	90.74	-0.38		114.99	119.51	+5.02	
203	100.7	98.57	-2.13		151.38	144.46	-6.97	
204	88.31	89.81	+1.50		119.50	124.30	+4.80	
206	100.7	103.07	+2.37		151.38	151.38	0.00	
207	99.64	98.78	-0.86		141.00	139.33	-1.67	
208	83.30	84.38	+0.88		107.78	117.00	+9.22	
209	80.74	82.45	+1.71		106.07	110.75	+4.68	
210	98.57	97.72	-0.65		132.66	130.90	-1.67	
211	97.50	98.57	+1.07		132.66	129.32	-3.34	
212	106.07	105.00	-1.07		156.00	168.00	+12.0	
213	89.81	88.87	-0.94		127.66	127.66	0.00	
214	91.50	90.74	-0.76		116.24	118.25	+2.01	
215	106.07	103.92	-2.15		151.38	146.76	-4.62	
216	98.81	91.68	+1.87		122.66	126.00	+3.39	
217	102.85	100.7	-2.15		146.76	151.38	+4.62	
218	89.81	93.55	+3.74		121.00	126.00	+5.00	
219	89.62	91.50	+1.88		121.00	118.74	-2.26	
Totals			+3.39	51.41			+26.87	463.95

t value = 0.556
not significant at 5% level
with 17 degrees of freedom

t value = 1.44
not significant at 5% level
with 17 degrees of freedom

TABLE 8

ERROR CONTROL STUDY FOR DENTAL AGE EVALUATIONS
FEMALES

	First Age				Second Age			
Code#	Time 1	Time 2	T2-T1	$(T2-T1)^2$	Time 1	Time 2	T2-T1	$(T2-T1)^2$
101	78.54	80.35	+1.81		100.00	102.22	+2.22	
102	75.26	73.99	-1.27		105.55	105.55	0.00	
103	88.64	89.03	+0.39		151.20	140.30	-10.90	
104	83.27	83.45	+0.18		118.58	116.82	-1.76	
105	84.77	85.93	+1.16		123.19	121.20	-1.99	
107	86.32	88.64	+2.32		132.20	131.20	-1.00	
108	85.15	87.48	+2.33		116.87	116.87	0.00	
109	104.44	97.87	-6.66		151.20	145.20	-6.00	
110	68.21	69.00	+0.79		90.77	95.60	+4.83	
111	79.81	85.93	+6.14		109.03	111.65	+2.62	
112	94.44	95.60	+1.16		158.40	145.20	-13.20	
113	84.00	82.36	-1.64		131.20	131.20	0.00	
114	82.18	84.00	+1.82		119.47	114.25	-5.22	
115	96.66	93.67	-2.99		171.00	158.40	-12.60	
117	74.90	78.54	+3.64		115.56	114.25	-1.31	
118	82.18	83.09	+0.91		119.47	119.47	0.00	
119	89.60	90.19	+0.59		131.20	133.38	+2.18	
121	82.91	81.08	-1.83		116.87	119.47	+2.60	
123	93.67	93.67	0.00		140.30	145.20	+4.90	
124	85.93	84.19	-1.74		129.60	123.19	-6.41	
Totals			+7.11	137.00			-41.04	636.56

t value = 0.616
not significant at 5% level
with 19 degrees of freedom

t value = 2.1693
significant at 5% level
with 19 degrees of freedom

TABLE 9

ERROR CONTROL STUDY FOR SKELETAL AGE EVALUATIONS
MALES

Code#	First Age Time 1	First Age Time 2	First Age T2-T1	First Age $(T2-T1)^2$	Second Age Time 1	Second Age Time 2	Second Age T2-T1	Second Age $(T2-T1)^2$
201	77.54	74.54	-3.00		132.08	128.31	-3.77	
202	96.00	89.38	-6.62		143.54	140.31	-3.23	
203	85.00	85.15	+0.15		135.23	137.08	+1.85	
207	75.00	68.25	-6.75		124.85	121.15	-3.70	
Totals			-16.22	98.41			-8.85	41.76

t value = 2.46
not significant at 5% level
with 3 degrees of freedom

t value = 1.625
not significant at 5% level
with 3 degrees of freedom

TABLE 10
ERROR CONTROL STUDY FOR SKELETAL AGE EVALUATIONS
FEMALES

Code#	First Age Time 1	First Age Time 2	First Age T2-T1	First Age $(T2-T1)^2$	Second Age Time 1	Second Age Time 2	Second Age T2-T1	Second Age $(T2-T1)^2$
101	84.46	88.15	+3.69		134.14	138.43	+4.29	
102	89.15	90.67	+1.52		135.43	133.29	-2.14	
103	96.08	98.62	+2.54		154.29	157.29	+3.00	
121	105.85	108.31	+2.46		156.00	152.57	-3.43	
124	100.69	95.85	-4.84		148.29	145.71	-2.58	

t value = 0.704
not significant at 5% level
with 5 degrees of freedom

t value = 0.541
not significant at 5% level
with 5 degrees of freedom

TABLE 11

STUDY OF ERROR IN MAKING DOUBLE DETERMINATIONS OF DENTAL AGE AT A LATER CHRONOLOGICAL AGE AS OPPOSED TO AN EARLIER CHRONOLOGICAL AGE. CALCULATIONS ARE EXPRESSED IN MONTHS OF AGE
FEMALES

Code #	Terminal Difference	Beginning Difference	T - B	$(T - B)^2$
101	2.22	1.81	+0.41	
102	0.00	1.27	-1.27	
103	10.9	0.39	+10.51	
104	1.76	0.18	+ 1.58	
105	1.99	1.16	+0.83	
107	1.00	2.32	-1.32	
108	0.00	2.33	-2.33	
109	6.00	6.66	-0.66	
110	4.83	0.79	+4.04	
111	2.62	6.14	-3.52	
112	13.2	1.16	+12.04	
113	0.00	1.64	-1.64	
114	5.22	1.82	+3.40	
115	12.6	2.99	+9.61	
117	1.31	3.64	-2.33	
118	0.00	0.91	-0.91	
119	2.18	0.59	+1.59	
121	2.60	1.83	+0.77	
123	4.90	0.00	+4.90	
124	6.41	1.74	+4.67	
			+40.37	458.51

t value = 2.02
significant at 5% level based on a one tailed test
with 19 degrees of freedom

TABLE 12

STUDY OF ERROR IN MAKING DOUBLE DETERMINATIONS OF DENTAL AGE AT A LATER CHRONOLOGICAL AGE AS OPPOSED TO AN EARLIER CHRONOLOGICAL AGE. CALCULATIONS ARE EXPRESSED IN MONTHS OF AGE

MALES

Code #	Terminal Difference	Beginning Difference	T - B	$(T - B)^2$
201	3.34	0.00	-3.34	
202	5.02	0.38	+4.64	
203	6.97	2.13	+4.84	
204	4.80	1.50	+3.30	
206	0.00	2.37	-2.37	
207	1.67	0.86	+0.81	
208	9.22	0.88	+8.34	
209	4.68	1.71	+2.97	
210	1.67	0.65	+1.02	
211	3.34	1.07	+2.27	
212	12.00	1.07	+10.93	
213	0.00	0.94	-0.94	
214	2.01	0.76	+1.25	
215	4.62	2.15	+2.47	
216	3.39	1.87	+1.52	
217	4.62	2.15	+2.47	
218	5.00	3.74	+1.26	
219	2.26	1.88	+0.38	
			+41.82	296.00

t value = 3.56
significant at 5% level based on a one tailed test
with 17 degrees of freedom

TABLE 13

STUDY OF ERROR IN MAKING DOUBLE DETERMINATIONS OF SKELETAL AGE AT A LATER CHRONOLOGICAL AGE AS OPPOSED TO AN EARLIER CHRONOLOGICAL AGE. CALCULATIONS ARE EXPRESSED IN MONTHS OF AGE
FEMALES

Code #	Terminal Difference	Beginning Difference	T - B	$(T - B)^2$
101	4.29	3.69	+0.60	
102	2.14	1.52	+0.62	
103	3.00	2.54	+0.46	
121	3.34	2.46	+0.97	
124	2.58	4.84	-2.26	
			+0.39	7.00

t value = 1.278
not significant at 5% level based on a one tailed test
with 4 degrees of freedom

TABLE 14

STUDY OF ERROR IN MAKING DOUBLE DETERMINATIONS OF SKELETAL AGE AT A LATER CHRONOLOGICAL AGE AS OPPOSED TO AN EARLIER CHRONOLOGICAL AGE. CALCULATIONS ARE EXPRESSED IN MONTHS OF AGE
MALES

Code #	Terminal Difference	Beginning Difference	T - B	$(T - B)^2$
201	3.77	3.00	+0.77	
202	3.23	6.62	-3.39	
203	1.85	0.15	+1.70	
207	3.70	6.75	-3.05	
			-3.97	24.27

t value = 0.761
not significant at 5% level based on a one tailed test
with 3 degrees of freedom

TABLE 15

AGES OF EACH SUBJECT AT THE BEGINNING
AND TERMINATION OF EXPERIMENT
FEMALES

Code #	Beginning Evaluations C.A.	D.A.	S.A.	Terminal Evaluations C.A.	D.A.	S.A.
101	90	79.45	84.46	139	101.11	134.14
102	92	74.63	89.15	141	105.55	135.43
103	90	88.84	96.08	144	145.75	154.29
104	95	83.36	79.15	143	117.70	137.14
105	89	85.35	81.69	137	122.20	141.00
107	90	87.48	80.08	138	131.70	122.31
108	103	86.32	88.23	151	116.87	162.00
109	91	101.11	103.00	138	148.20	159.00
110	84	68.61	82.38	132	93.19	122.77
111	91	82.87	84.69	138	110.34	136.29
112	96	95.02	94.38	144	151.80	147.43
113	84	83.18	93.15	132	131.20	146.57
114	90	83.09	94.31	137	116.86	164.57
115	96	95.17	96.23	147	164.70	150.43
117	90	76.72	87.00	139	114.91	139.38
118	96	82.64	92.24	150	119.47	144.46
119	97	89.90	101.69	147	132.29	150.92
121	96	82.00	105.85	144	118.17	156.00
123	99	93.67	100.54	149	142.75	155.14
124	91	85.06	100.69	142	126.40	148.29

C.A. = chronological age in months
D.A. = dental age in months
S.A. = skeletal age in months

TABLE 16

AGES OF EACH SUBJECT AT THE BEGINNING
AND TERMINATION OF EXPERIMENT
MALES

Code #	Beginning Evaluations			Terminal Evaluations		
	C.A.	D.A.	S.A.	C.A.	D.A.	S.A.
201	91	98.57	77.54	138	130.99	132.08
202	97	90.93	96.00	144	117.00	143.54
203	96	99.64	85.00	144	147.92	135.23
204	84	89.06	89.85	132	121.92	138.46
206	96	101.89	95.38	144	151.38	151.50
207	96	99.21	75.00	145	140.17	124.85
208	84	83.74	72.25	133	112.39	124.15
209	89	81.60	75.31	131	108.41	130.15
210	95	98.25	95.54	143	131.83	146.31
211	97	98.04	79.23	145	130.99	131.23
212	103	105.54	80.54	151	162.00	134.77
213	96	89.34	84.46	144	127.66	134.31
214	91	91.12	70.73	139	117.25	128.92
215	95	105.00	94.38	143	149.07	148.15
216	84	90.75	59.83	132	124.31	113.92
217	95	101.78	104.46	145	149.07	150.92
218	91	91.68	84.77	138	123.5	137.08
219	96	90.56	92.38	143	119.87	147.69

C.A. = chronologica. age in months
D.A. = dental age in months
S.A. = skeletal age in months

TABLE 17

TEST TO DETERMINE IF THE SKELETAL AGE WAS EQUIVALENT TO DENTAL AGE IN MONTHS

Beginning Evaluations
Control Group

FEMALES					MALES				
Code #	S.A.	D.A.	SA-DA	$(SA-DA)^2$	Code #	S.A.	D.A.	SA-DA	$(SA-DA)^2$
111	84.69	82.87	+1.82		203	85.00	99.64	-14.64	
112	94.38	95.02	-0.64		210	95.54	98.25	- 2.71	
113	93.15	83.18	+9.97		212	80.54	105.54	-25.00	
118	92.24	82.64	+9.60		217	104.46	101.78	+ 2.68	
119	101.69	89.90	+11.79						
124	100.69	85.06	+15.63						
			+48.17	578.58				-39.67	853.86

t value = 3.1739
significant at 5% level
with 5 degrees of freedom

t value = 1.6013
not significant at 5% level
with 3 degrees of freedom

S.A. = skeletal age in months
D.A. = dental age in months

TABLE 18

TEST TO DETERMINE IF THE SKELETAL AGE WAS EQUIVALENT TO DENTAL AGE IN MONTHS

Beginning Evaluations
Experimental Group

FEMALES					MALES				
Code#	S.A.	D.A.	SA-DA	$(SA-DA)^2$	Code#	S.A.	D.A.	SA-DA	$(SA-DA)^2$
101	84.46	79.45	+5.01		201	77.54	98.57	-21.03	
102	89.15	74.63	+14.52		202	96.00	90.93	+ 5.07	
103	96.08	88.84	+ 7.24		204	89.85	89.06	+ 0.79	
104	79.15	83.36	- 4.21		206	95.38	101.89	- 6.51	
105	81.69	85.35	- 3.66		207	75.00	99.21	-24.21	
107	80.08	87.48	- 7.40		208	72.25	83.74	-11.49	
108	88.23	86.32	+ 1.91		209	75.31	81.60	- 6.29	
109	103.00	101.11	+ 1.89		211	79.23	94.04	-14.81	
110	82.38	68.61	+13.77		213	84.46	89.34	- 4.88	
114	94.31	83.09	+11.22		214	70.73	91.12	-20.39	
115	96.23	95.17	+ 1.06		215	94.38	105.00	-10.62	
117	87.00	76.72	+10.28		216	59.83	90.75	-30.92	
121	105.85	82.00	+23.85		218	84.77	91.68	- 6.91	
123	100.54	93.67	+ 6.87		219	92.38	90.56	+ 1.82	
			+82.35	1419.77				-150.38	3047.47

t value = 2.5937
significant at 5% level
with 13 degrees of freedom

t value = 3.8261
significant at 5% level
with 13 degrees of freedom

S.A. = skeletal age in months
D.A. = dental age in months

TABLE 19

TEST TO DETERMINE IF THE SKELETAL AGE WAS EQUIVALENT TO DENTAL AGE IN MONTHS

Terminal Evaluations
Control Group

FEMALES					MALES				
Code#	S.A.	D.A.	SA-DA	$(SA-DA)^2$	Code#	S.A.	D.A.	SA-DA	$(SA-DA)^2$
111	136.29	110.30	+25.95		203	135.23	147.92	-12.69	
112	147.43	151.80	- 4.37		210	146.31	131.83	+14.48	
113	146.57	132.20	+15.37		212	134.77	162.00	-27.23	
118	144.46	119.47	+24.99		217	150.92	149.07	+ 1.85	
119	150.92	132.29	+18.63						
124	148.29	126.40	+21.89						
			+102.46	2379.49				-23.59	115.60

t value = 3.7292
significant at 5% level
with 5 degrees of freedom

t value = 0.6541
not significant at 5% level
with 3 degrees of freedom

S.A. = skeletal age in months
D.A. = dental age in months

TABLE 20

TEST TO DETERMINE IF THE SKELETAL AGE WAS EQUIVALENT TO DENTAL AGE IN MONTHS

Terminal Evaluations
Experimental Group

FEMALES					MALES				
Code#	S.A.	D.A.	SA-DA	$(SA-DA)^2$	Code#	S.A.	D.A.	SA-DA	$(SA-DA)^2$
101	134.14	101.11	+33.03		201	132.08	130.99	+ 1.09	
102	135.43	105.55	+29.88		202	143.54	117.00	+26.54	
103	154.29	145.75	+ 8.54		204	138.46	121.92	+16.54	
104	137.14	117.70	+19.44		206	151.50	151.38	+ 0.12	
105	141.00	122.20	+18.80		207	124.85	140.17	-15.32	
107	122.31	131.70	- 9.39		208	124.15	112.39	+11.76	
108	162.00	116.87	+45.13		209	130.15	108.41	+21.74	
109	159.00	148.20	+10.80		211	131.23	130.99	+ 0.24	
110	122.77	93.19	+29.58		213	134.31	127.66	+ 6.65	
114	164.57	116.86	+47.71		214	128.92	117.25	+11.67	
115	150.43	164.70	-14.27		215	148.15	149.07	- 0.92	
117	139.38	114.91	+24.47		216	113.92	124.31	-10.39	
121	156.00	118.17	+37.83		218	137.08	123.50	+13.58	
123	155.14	142.75	+12.39		219	147.69	119.87	+27.82	
			+293.94	10567.86				+111.12	3072.41

t value = 4.2726
significant at 5% level
with 13 degrees of freedom

t value = 2.2882
significant at 5% level
with 13 degrees of freedom

S.A. = skeletal age in months
D.A. = dental age in months

TABLE 21

TEST TO DETERMINE IF THE SKELETAL AGE WAS EQUIVALENT TO DENTAL AGE POOLING THE DATA FOR MALES AND FEMALES, CONTROL AND EXPERIMENTAL GROUPS. ALL CALCULATIONS IN MONTHS

Beginning Evaluations

Control Group Males and Females					Experimental Group Males and Females				
Code#	S.A.	D.A.	SA-DA	$(SA-DA)^2$	Code#	S.A.	D.A.	SA-DA	$(SA-DA)^2$
111	84.69	82.87	+ 1.82		101	84.46	79.45	+ 5.01	
112	94.38	95.02	- 0.64		102	89.15	74.63	+14.52	
113	93.15	83.18	+ 9.97		103	96.08	88.84	+ 7.24	
118	92.24	82.64	+ 9.60		104	79.15	83.36	- 4.21	
119	101.67	89.90	+11.79		105	81.69	85.35	- 3.66	
124	100.69	85.06	+15.63		107	80.08	87.48	- 7.40	
203	85.00	99.64	-14.64		108	88.23	86.32	+ 1.91	
210	95.59	98.25	- 2.71		109	103.00	101.11	+ 1.89	
212	80.54	105.54	-25.00		110	82.38	68.61	+13.77	
217	104.46	101.78	+ 2.68		114	94.31	83.09	+11.22	
					115	96.23	95.17	+ 1.06	
					117	87.00	76.72	+10.28	
					121	105.85	82.00	+23.85	
					123	100.54	93.67	+ 6.87	
					201	77.54	98.57	-21.03	
					202	96.00	90.93	+ 5.07	
					204	89.85	89.06	+ 0.79	
					206	95.38	101.89	- 6.51	
					207	75.00	99.21	-24.21	
					208	72.25	83.74	-11.49	
					209	75.31	81.60	- 6.29	
					211	79.23	94.04	-14.81	
					213	84.46	89.34	- 4.88	
					214	70.73	91.12	-20.99	
					215	94.38	105.00	-10.62	
					216	59.83	90.75	-30.92	
					218	84.77	91.68	- 6.91	
					219	92.38	90.56	+ 1.82	
			+ 8.50	1432.44				-68.03	4467.24

t value = 0.2136
not significant at 5% level
with 9 degrees of freedom

t value = 1.0187
not significant at 5% level
with 27 degrees of freedom

S.A. = skeletal age in months
D.A. = dental age in months

TABLE 22

TEST TO DETERMINE IF THE SKELETAL AGE WAS EQUIVALENT TO DENTAL AGE POOLING THE DATA FOR MALES AND FEMALES, CONTROL AND EXPERIMENTAL GROUPS. ALL CALCULATIONS IN MONTHS

Terminal Evaluations in Months

Control Group Males and Females					Experimental Group Males and Females				
Code #	S.A.	D.A.	SA-DA	$(SA-DA)^2$	CODE #	S.A.	D.A.	SA-DA	$(SA-DA)^2$
111	136.29	110.34	+25.95		101	134.14	101.11	+33.03	
112	147.43	151.80	- 4.37		102	135.43	105.55	+29.88	
113	146.57	131.20	+15.37		103	154.29	145.75	+ 8.54	
118	144.46	119.47	+24.99		104	137.14	117.70	+19.44	
119	150.92	132.29	+18.63		105	141.00	122.20	+18.80	
124	148.29	126.40	+21.89		107	122.31	131.70	- 9.39	
203	135.23	147.92	-12.29		108	162.00	116.87	+45.13	
210	146.31	131.82	+14.48		109	159.00	148.20	+10.80	
212	134.77	162.00	-27.23		110	122.77	93.19	+29.59	
217	150.92	149.07	+ 1.85		114	164.57	116.86	+47.71	
					115	150.43	164.70	-14.27	
					117	139.38	114.91	+24.47	
					121	156.00	118.17	+37.83	
					123	155.14	142.75	+12.39	
					201	132.08	130.99	+ 1.09	
					202	143.54	117.00	+26.54	
					204	138.46	121.92	+16.54	
					206	151.50	151.38	+ 0.12	
					207	124.85	140.17	-15.32	
					208	125.15	112.39	+11.76	
					209	130.15	108.41	+21.74	
					211	131.23	130.99	+ 0.24	
					213	134.31	127.66	+ 6.65	
					214	128.92	117.25	+11.67	
					215	148.15	149.07	- 0.92	
					216	113.92	124.31	-10.39	
					218	137.08	123.50	+13.58	
					219	147.69	119.87	+27.82	
			+78.87	3495.09				+405.06	13640.27

t value = 1.3964
not significant at 5% level
with 9 degrees of freedom

t value = 4.5077
significant at 5% level
with 27 degrees of freedom

S.A. = skeletal age in months
D.A. = dental age in months

TABLE 23

TESTS TO DETERMINE IF THE SKELETAL AGE-DENTAL AGE DIFFERENCES BETWEEN BEGINNING AND TERMINAL EVALUATIONS IN THE MALE CONTROL AND EXPERIMENTAL GROUPS WERE STATISTICALLY SIGNIFICANT. CALCULATIONS ARE IN MONTHS OF AGE

MALES

Control Groups				Experimental Groups			
d2	d1	d2-d1	$(d2-d1)^2$	d2	d1	d2-d1	$(d2-d1)^2$
-12.69	-14.64	+1.95		+ 1.09	-21.03	+22.12	
+14.48	- 2.71	17.19		+26.54	+ 5.07	+21.47	
-27.23	-25.00	-2.23		+16.54	+ 0.79	+15.75	
+ 1.85	+ 2.68	-0.83		+ 0.12	- 6.51	+ 6.63	
				-15.32	-24.21	+ 8.89	
				+11.76	-11.49	+23.25	
				+21.74	- 6.29	+28.03	
				+ 0.24	-14.81	+15.05	
				+ 6.65	- 4.88	+11.53	
				+11.67	-20.39	+32.06	
				- 0.92	-10.62	+ 9.70	
				-10.39	-30.62	+20.53	
				+13.58	- 6.91	+20.49	
				+27.58	+ 1.82	+26.00	
		+16.08	304.96			+261.50	5646.25

t value = 0.8993
not significant at 5% level
with 3 degrees of freedom

t value = 9.130
significant at 5% level
with 13 degrees of freedom

d2 = difference in months between skeletal age and dental age for terminal evaluations.
d1 = difference in months between skeletal age and dental age for the beginning evaluations.

TABLE 24

TESTS TO DETERMINE IF THE SKELETAL AGE-DENTAL AGE DIFFERENCES BETWEEN BEGINNING AND TERMINAL EVALUATIONS IN THE FEMALE CONTROL AND EXPERIMENTAL GROUPS WERE STATISTICALLY SIGNIFICANT. CALCULATIONS ARE IN MONTHS OF AGE

FEMALES

Control Groups				Experimental Groups			
d2	d1	d2-d1	$(d2-d1)^2$	d2	d1	d2-d1	$(d2-d1)^2$
+25.95	+ 1.81	+24.13		+33.03	+ 5.01	+28.02	
- 4.37	- 0.64	- 3.37		+29.88	+14.52	+15.36	
+15.37	+ 9.97	+ 5.40		+ 8.54	+ 7.24	+ 1.30	
+24.99	+ 9.60	+15.39		+19.44	- 4.21	+23.65	
+18.63	+11.76	+ 6.84		+18.80	- 3.66	+22.46	
+21.89	+15.63	+ 6.26		- 9.39	- 7.40	- 1.99	
				+45.13	+1. 91	+43.22	
				+10.18	+ 1.89	+ 8.91	
				+29.58	+13.77	+15.81	
				+47.71	+11.22	+36.49	
				-14.27	+ 1.06	-15.33	
				+24.47	+10.28	+14.19	
				+37.83	+23.85	+13.98	
				+12.39	+ 6.87	+ 5.52	
		+54.29	948.16			+211.59	6281.58

t value = 2.319
not significant at 5% level
with 5 degrees of freedom

t value = 3.667
significant at 5% level
with 13 degrees of freedom

d2 = difference in months between skeletal age and dental age for terminal evaluations.

d1 = difference in months between skeletal age and dental age for beginning evaluations.

FINDINGS AND DISCUSSION

The experimental data were examined statistically to determine the methodological error associated with the skeletal and dental age assessments. There was no systematic error, using the 5 per cent level of confidence, between the first and second evaluations of the same records for any of the groups considered except for the terminal evaluations of the dental age for the experimental females (Tables 7, 8, 9, and 10). The error between double determinations associated with this group may be attributed to the dental age evaluations of subjects 103, 112, and 115. For the remainder of the experiment the mean values between the first and second assessments of dental age were used as the dental age for each of the subjects. Ten of the skeletal evaluations were assessed twice, and since there was no significant difference between the two evaluations (Tables 9 and 10), the initial assessment of skeletal age for each subject was used throughout the experiment.

All subjects were evaluated for skeletal age and dental age at two points in time. The beginning evaluation was made at approximately eight years of age, and the terminal evaluation at approximately twelve years of age. Statistical tests (Tables 11 and 12) indicated that it was more difficult to make dental age assessments at the terminal age than at the beginning age. This finding suggests that the developmental stages of root formation which occur at a later chronological age are more difficult to evaluate than the earlier developmental stages of crown formation. Assessments of dental age based on developmental stages of root formation become progressively less accurate as the

chronological age increases. In contrast to this finding, tests of the skeletal age assessments (Tables 13 and 14) revealed that there was no statistically significant error in evaluating skeletal age at the terminal age than at the beginning age. These results would be expected because of the reliability of the standards used (3).

Student's "t" tests were performed at the beginning and terminal stages of the experiment to determine if the skeletal age was equal to the dental age in the control and experimental groups (Tables 17, 18, 19, and 20). Only the male control group showed no significant difference between the skeletal age and dental age at both the beginning and terminal observations. Results indicated that in all of the other groups the skeletal age and dental age were significantly different at both the beginning and terminal ages. These results are misleading because they do not take into consideration which value is the greatest and the direction of change. It should be noted that in all groups the skeletal age increased more than the dental age when comparing the beginning and terminal observations. The increase was greatest in the experimental group and most noticeable in the experimental males. It will be noted from Tables 18 and 20 than in the experimental male group the total skeletal age-dental age differences changed from -150.38 months at the beginning to +111.12 months at the termination. This is a mean increase of 18.7 months of skeletal age over dental age.

When the male and female data were pooled and the same tests were applied, the results were more indicative of the true difference between the experimental and control groups (Tables 21 and 22). These results indicate that at eight years of age there was no statistically significant difference between skeletal age and the dental age for

either the experimental or control group. When examining the two groups four years later at age twelve, there was a statistically significant difference between the skeletal age and dental age for the experimental group, but not for the control group. The children who had good skeletal balance and who developed good dental occlusion showed no statistically significant difference between the skeletal age and dental age at either the beginning or the termination of the experiment. The children who had good skeletal balance but malocclusion of the permanent dentition showed no statistically significant difference between the skeletal age and dental age at the beginning of the experiment. The children in the experimental group, however, did show a statistically significant difference between the skeletal age and the dental age at the time of the terminal evaluation. The difference between dental age and skeletal age in the experimental groups may be attributed to retarded development of the dentition. In Figure 2 are plotted the mean skeletal ages and dental ages as they relate to the chronological ages for the children in the experimental group. Figure 3 includes the same information for the control group. The two graphs illustrate that in both the control and experimental groups the skeleton matures more rapidly than the dentition and that the terminal evaluation of the skeletal age was in close harmony with the chronological age. Although there was a discrepancy between the dental and skeletal evaluations for the control group it was much less than in the experimental group. Figure 3 illustrates relatively harmonious skeletal and dental maturation in the control group. Figure 2 shows less harmony between skeletal and dental maturation in the experimental group than in the control group.

The discussion thus far has been concerned primarily with the question; is the skeletal age equal to the dental age in the various groups tested? No one group at either the beginning or terminal observations showed complete harmony between skeletal and dental age evaluations. Additional tests were conducted to determine if the differences between the skeletal and dental ages at the beginning of the experiment were significantly different from those at the termination of the experiment (Tables 23 and 24).

This series of tests demonstrated that there was no statistically significant difference between beginning and terminal skeletal age-dental age differences between the control male and female groups. In other words, the relationship of the skeletal age to the dental age did not change significantly during the four year period of the study in the control group. Although the dental age was slightly less than the skeletal age, this difference did not change significantly with the passage of time. In the control group the dentition and the skeleton matured harmoniously in relation to each other. In contrast, the experimental group showed a statistically significant difference between beginning and terminal skeletal age-dental age differences. The mean increase in months of skeletal age over dental age from the beginning to the terminal stage for each group is illustrated in Figure 4. The graph illustrates the magnitude of the discrepancy between the skeletal age-dental age differences at the beginning and terminal evaluations for each of the groups. It is obvious that the discrepancy between skeletal and dental maturation is much greater in the experimental group. The lack of harmony between the skeletal and dental maturation in the experimental group may be

attributed to retarded dental development. It appears that even in children who possess good skeletal balance, retarded or slow maturation of the dentition may be indicative of a developing dental malocclusion.

--------- = Skeletal Age in months
— — — = Dental Age in months
———— = Chronological Age in months

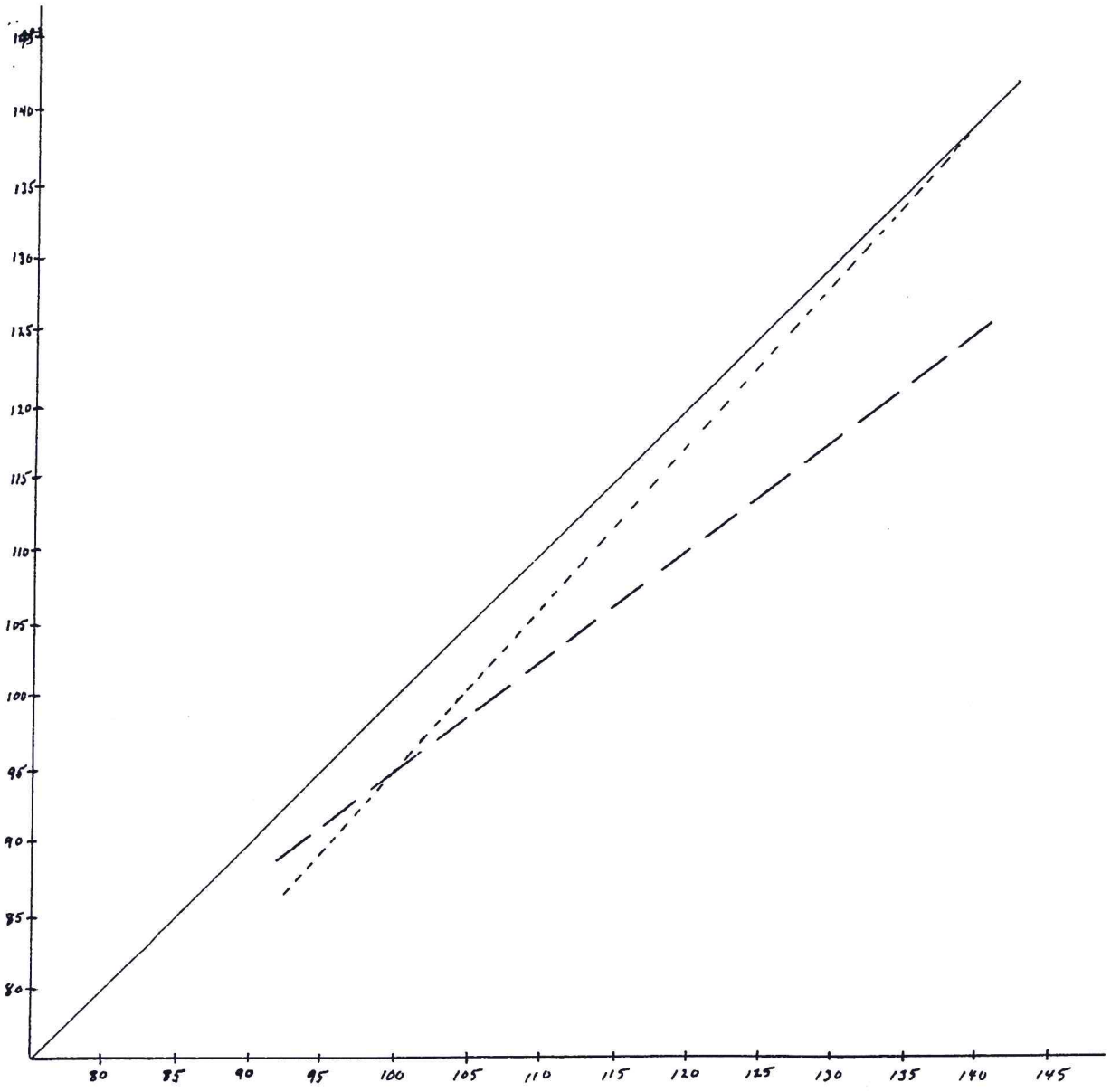

Fig. 2.--Mean skeletal age and dental age for the experimental group male and female data pooled. Chronological age is plotted on the abscissa; skeletal and dental age are plotted on the ordinate.

- - - - - - - = Skeletal Age in months
— — — = Dental Age in months
——————— = Chronological Age in months

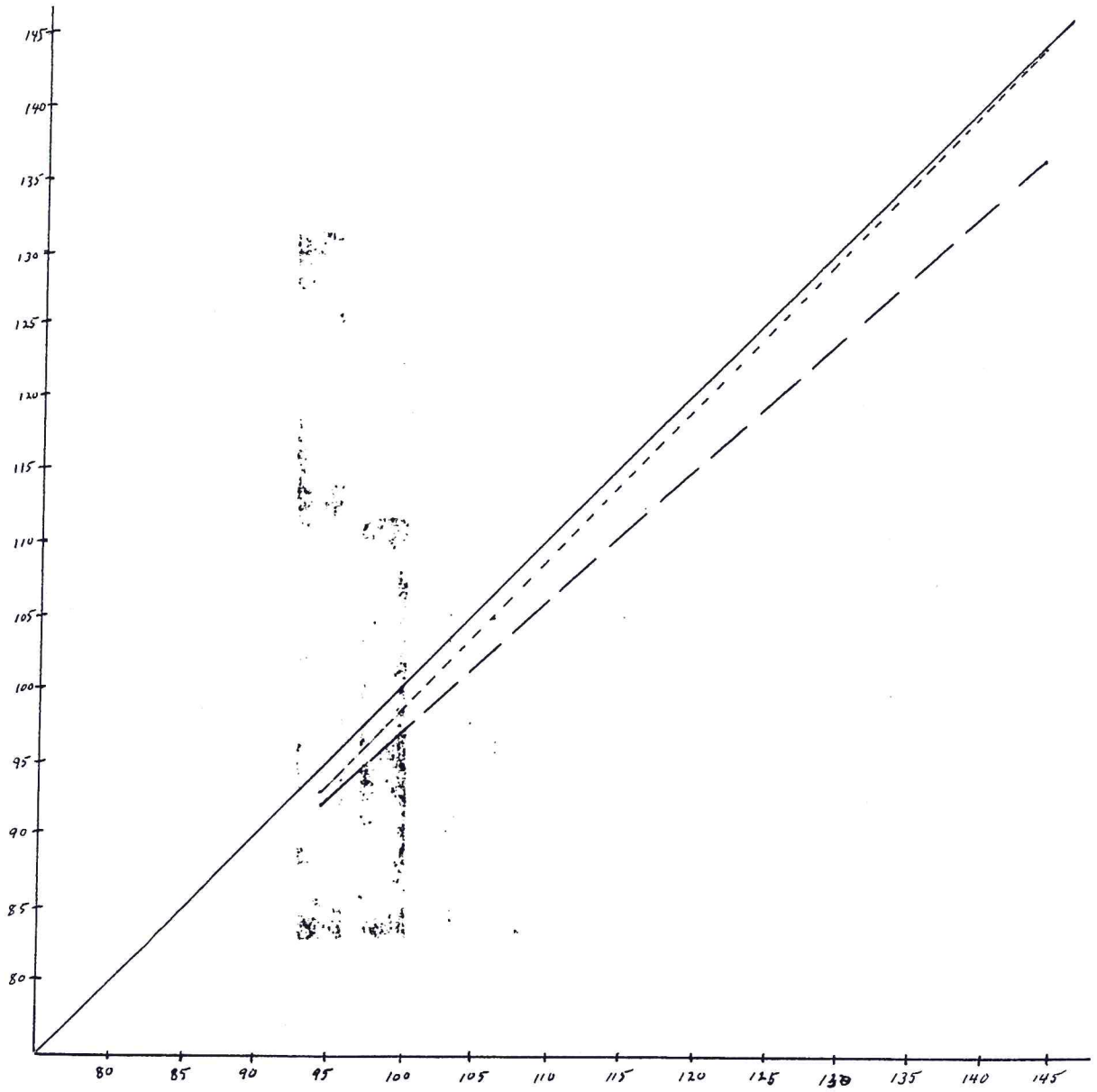

Fig. 3.--Mean skeletal age and dental age for the control group male and female data pooled. Chronological age is plotted on the abscissa; skeletal and dental age are plotted on the ordinate.

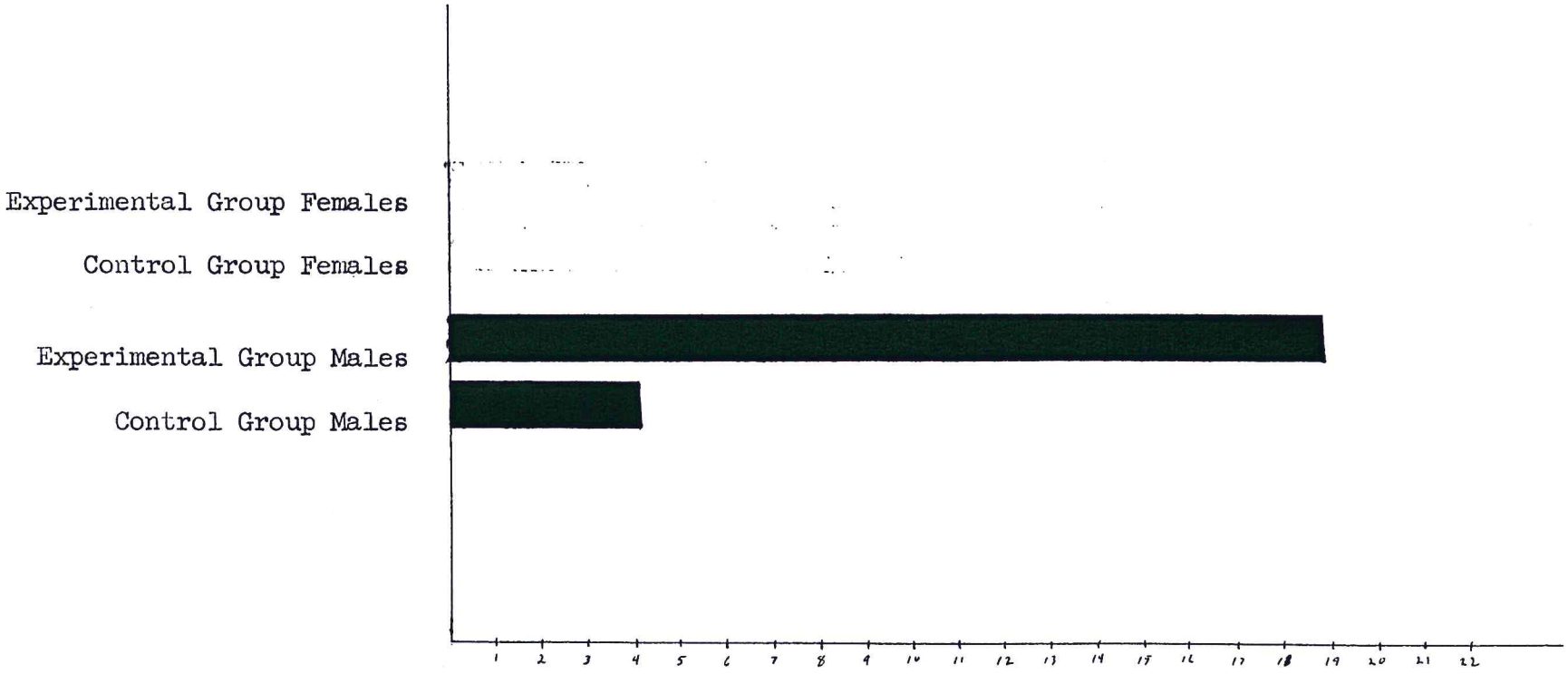

Fig. 4.--Mean increase in months of skeletal age over dental age from the beginning to the terminal evaluation.

SUMMARY AND CONCLUSIONS

A longitudinal investigation was conducted to observe and to compare the dental and skeletal maturation of children with different types of dental occlusion.

The sample studied was composed of thirty-eight white caucasian children, eighteen males and twenty females. All subjects had good crainiofacial skeletal balance and were separated into control and experimental groups according to their individual dental characteristics.

Student's "t" Tests were utilized to interpret the experimental data. The following conclusions were formed:

1. It was demonstrated that dental age evaluations could be repeated with a reasonable degree of accuracy using Nolla's standards except for the terminal evaluations of the female experimental group.
2. The high reproducibility of skeletal age assessments, using Grelich and Pyle's Radiographic Atlas of Skeletal Development of the Hand and Wrist, was confirmed.
3. It is more difficult to reproduce dental age assessments at chronological age twelve years, than at chronological age eight years.
4. In the male control group no statistically significant difference was found between the skeletal age and the dental age at either the beginning or terminal evaluations.

5. There was a statistically significant difference between the skeletal age and the dental age, at both beginning and terminal evaluations in the following groups: female control, male experimental, and female experimental.
6. When the data for the male and female experimental groups were pooled there were statistically significant differences between the skeletal age and the dental age at the terminal evaluation, but not at the beginning evaluation.
7. When the data for the male and female control groups were pooled there were no statistically significant differences between the skeletal age and dental age at either the beginning or terminal evaluations.
8. The skeletal age increased more than the dental age in all groups during the time interval studied. The increase was greatest in the experimental group.
9. In the control group, the skeletal age-dental age differences at the beginning evaluations were not significantly different from those at the terminal evaluations.
10. In the experimental group, the skeletal age-dental age differences at the beginning evaluations were significantly different from those at the terminal evaluations.
11. The results of this study indicate that even in children who have good craniofacial skeletal relationships, a retarded or slowly maturing dentition could contribute to and be indicative of a developing dental malocclusion.

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