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Original Article

Correlation of skeletal maturity indicators to dental maturity indicators and chronological age

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ABSTRACT

Introduction: Age assessment is an important facet in providing information for demographic studies and was of clinical use to diagnose and plan treatment. It is of great significance to know a child's growth status, for orthodontic diagnosis and modification of treatment planning. Also, it is used in medico-legal cases and legal age for criminal responsibility.

Aim and objectives: to correlate Skeletal Maturity Indicators and Dental Maturity Indicators to Chronological Age in children of 10-14 years of age. Also, 1) To evaluate interrelationship between chronological age, dental and skeletal age. 2)To compare chronological age to skeletal age and dental age and both skeletal age determination methods. 3) To assess age determination methods for sexual dimorphism.

Material and methods: the data for the present study was selected according to specified inclusion and exclusion criteria. Panoramic and hand wrist radiographs of 120 boys and girls were selected in the age group of 10 to 14 years. These radiographs were then interpreted for dental age (modified Demirjian's method) and skeletal age (Fishman's and method) to compare with Chronological age.

Results: statistically significant results were obtained for various age estimation comparisons in total sample and age groups (Group A to Group H). Also, very strong correlations were found between various methods in total sample as well as in different gender groups.

Conclusion: Chronological age correlated maximum with dental age, then skeletal age (Fishman SMI > Bjork's SMI). Both skeletal age estimation methods showed significant differences in total sample. Also, no set pattern was observed when chronological age was compared to skeletal age.

Keywords: Chronological age, modified Demirjian's method, Fishman's SMI, Bjork's SMI

INTRODUCTION:

Age assessment was an important facet in providing information for demographic studies and was of clinical use to diagnose and plan treatment[1,2]. It was of great significance to know a child's growth status, timing being especially important for orthodontic diagnosis and modification of treatment planning influencing prognosis of orthodontic intervention[3]. However, growth rate was not equal at all the time; there were phases of acceleration of growth called "Growth spurts"[1]. Every skeletal and muscular dimension seems to be involved during this period which was advantageous for certain types of growth modulation treatment[1]. Thus, prediction of the timing and the amount of active growth of the craniofacial complex was very important to the orthodontist[1]. This was especially true when treatment planning involves modification of facial growth.

Growth can be estimated by age, height weight index, change in voice, onset of menarche etc[4]. Chronologic age, though being prime, may not be the only reliable indicator to evaluate maturity of child. Considerable variations in the development among children of same chronologic or calendar age have led to the concept of biological maturity of the body[5]. Taranger J considered biological maturation as a series of gradual transformation going in a human body from conception to death as a part of life cycle of an organism[6]. It was measured in any of four physiological divisions: somatic, sexual, skeletal and dental concurrent with chronologic age[1,7,8].

Chronologic age was the simplest of all, being calculated from date of birth of an individual. Skeletal age was assessed from radiographic analysis of certain bones – their appearance, changes in their shapes and sizes. To name some: foot, ankle, hip, elbow, cervical vertebrae and hand-wrist region[3]. Of these the hand wrist radiographs were most commonly used to evaluate skeletal maturation as it possesses many bones and epiphyses that mature in a well-defined progression over time, which can be easily evaluated on a single radiograph[1,8]. The progression of events might therefore provide not just an assessment of developmental status, but can also be used to predict the patient's growth status mainly during puberty[1].

Not only bones, developmental status of teeth also can provide an insight into the age of a subject. Human dentition follows a reliable and predictable developmental sequence, beginning about four months after conception and continuing to the beginning of the third decade of life when development of all the permanent teeth was completed[6]. This can be utilised in determining what was called "Dental age". Dental age was determined by eruption of teeth at level of mineralization[1,6,9-11]. Since process of mineralization was genetically determined it was preferred to eruption sequence for estimation of dental age[1].

The importance of age estimation cannot be denied in Orthodontics as well. Growth modifications or redirection treatment was possible only when the subject was in growing age[3]. Therefore, it was of prime importance to correlate chronologic age to skeletal age and dental age for successful outcome of treatment. However, racial variations do exist. Therefore, this study was conducted to correlate Skeletal Maturity Indicators and Dental Maturity Indicators to Chronological Age in children of 10-14 years of age. Along with the objectives 1) To evaluate interrelationship between chronological age, dental and skeletal age in children from 10 to 14 years of age. 2)To compare chronological age to skeletal age (Fishman SMI & Bjork's SMI) and to dental age using (modified Demirjian's method). 3) To compare both skeletal age determination methods for its applicability in Gujarati children of 10-14 years of age. 4) To assess these age determination methods for sexual dimorphism.

MATERIALS AND METHODS:

The study was conducted at the Department of Orthodontics and Dentofacial Orthopaedics, Government Dental College & Hospital, Ahmedabad. The sample for study consists of 240 panoramic radiographs and 240 hand wrist radiographs of left hand of 120 boys and 120 girls randomly selected from municipal schools of Ahmedabad in the age group of 10 to 14 years known Chronological age.

Subject criteria:

Inclusion criteria:

- Chronological age ranging from 10 to 14 years.
- Gujarati origin.

- No previous history of any serious illness, trauma or disease in orofacial region
- No visible dental or facial asymmetry
- No history of orthodontic treatment or extraction of any permanent teeth.

Exclusion criteria:

- Deformed images affecting estimation of tooth development and/or skeletal maturity stages.
- Abnormal dental conditions such as periapical lesions, congenitally missing teeth etc.
- History of systemic disease that could affect the presence and development of mandibular permanent teeth.

These subjects were divided into four groups according to Chronological age and further subdivided into male and female category (Table 1). Each group consisted 30 subjects.

Methods of Data Collection:

Chronological age was calculated by subtracting the birth date from the date on which the radiographs was taken[2]. Decimal age was taken for simplicity of statistical calculation and ages were estimated on yearly basis e.g., 10 years 9 months as 10.75 years and it was considered in 10 - 11 years age group.

Digital panoramic radiographs and hand-wrist radiographs of each subject were obtained using A S Stropan 2000 digital x-ray unit, for assessment of dental maturity and skeletal maturity respectively.

These radiographs were then interpreted for dental age by Demirjian's method modified for Indian population and skeletal age by Fishman's and Bjork, Grave and Brown's method to compare with Chronological age.

Assessment of dental maturation:

The method made use of mandibular permanent teeth on left side from central incisor to third molar on orthopantomogram. Corresponding various stages of tooth formation from tooth development chart were recorded for each tooth, converted into scores and added. The maturity score was calculated using Modified Demirjian's Index[12]. If any tooth was missing on left side, corresponding right side tooth was utilized.

Assessment of Skeletal Maturity:

1. BJORK, GRAVE AND BROWN METHOD[13]: They have divided skeletal development into 9 stages. Each of these stages represents a level of skeletal maturity. Appropriate Chronological age for each stage was given by Schopf in 1978.
2. FISHMAN'S SKELETAL MATURITY INDICATORS[14,15]: Proposed by Leonard S. Fishman in 1982. Makes use of anatomical sites located on thumb, third finger, fifth finger and radius. Eleven discrete adolescent skeletal maturity indicators (S.M.I) covering the entire period of adolescent development have been described. The Fishman's system of interpretation uses four stages of bone maturation. They are: 1) Epiphysis equal in width to diaphysis 2) Appearance of adductor sesamoid of the thumb. 3) Capping of epiphysis 4) Fusion of epiphysis.

Statistical analysis:

The statistical methods that were implied in the present study: Mean, Standard deviation, Standard error, P value, Paired t-test and Spearman's correlation coefficient (r). Statistical analysis was performed using SPSS version 23.

RESULTS:

The results were presented from Table 2 to table 16. Table 2 represents the mean of total sample (10-14 years) for chronological, skeletal and dental age. Table 3 represents mean value of chronological, skeletal and dental age of boys and girls separately divided into four different age groups from 10 to 14 years of age. Few variations were observed after obtaining the mean values for each of chronological age, skeletal age and dental age in all the age groups of boys and girls. Paired t test was carried out to compare chronologic age to skeletal age and dental age. Table 5 to table 13 shows the results of paired t test for all age groups of 11-14 years for both boys and girl. After comparison of individual age estimation in all group's strength of relationship between Chronological age, Skeletal age (Fishman's SMI & Bjork's method) and Dental age. Table 14 to Table 16 shows correlation between various age estimation methods which was obtained using Spearman's correlation coefficient (r).

BOYS	Age (years)	GIRLS
Group A	10-11	Group E
Group B	11-12	Group F
Group C	12-13	Group G
Group D	13-14	Group H

Table 1: Division of subjects

OVERALL		CHRONOLOGICAL AGE		FISHMAN'S SMI		BJORK SMI		DENTAL AGE	
Age Group	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD
10-11 years	60	10.50	0.32	10.95	0.35	10.39	0.59	10.42	0.44
11-12 years	60	11.39	0.31	11.46	0.32	11.74	0.87	11.43	0.27
12-13 years	60	12.37	0.32	12.38	0.38	12.81	0.49	12.48	0.32
13-14 years	60	13.57	0.34	13.88	0.50	13.45	0.59	13.98	0.53

Table 2: Mean, S.D of total sample (10-14 years of age) for Chronological age, Skeletal age and Dental age

MALE	N	CHRONOLOGICAL AGE		FISHMAN'S SMI		BJORK SMI		DENTAL AGE	
Age Group		Mean	SD	Mean	SD	Mean	SD	Mean	SD
A	30	10.47	0.30	10.70	0.28	10.60	0.00	10.60	0.20
B	30	11.25	0.14	11.43	0.26	12.18	0.61	11.33	0.24
C	30	12.36	0.32	12.25	0.27	12.50	0.42	12.59	0.39
D	30	13.60	0.34	13.90	0.67	13.50	0.75	13.73	0.58

Table 3(A): Mean, S.D of Chronological age, Skeletal age and Dental age for 120 boys with 10-14 years of age. (Group A –D)

Female		Chronological Age		Fishman's SMI		BJORK SMI		Dental Age	
Age Group	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD
E	30	10.53	.351	11.19	.219	10.17	.783	10.24	.532
F	30	11.54	.357	11.48	.372	11.29	.869	11.54	.250
G	30	12.37	.323	12.50	.430	13.11	.334	12.37	.188
H	30	13.55	0.34	13.86	0.24	13.40	0.38	14.23	0.31

Table 3(B): Mean, S.D of Chronological age, Skeletal age and Dental age for 120 girls with 10-14 years of age. (Group E-H)

Comparison	Pair
Chronological Age	Pair 1
Fishman's SM1	
Chronological Age	Pair 2
Bjork, Grave and Brown SMI	
Chronological Age	Pair 3
Dental Age	
Fishman's SMI	Pair 4
Bjork, Grave and Brown SMI	
Fishman's SMI	Pair 5
Dental Age	
Bjork, Grave and Brown SMI	Pair 6
Dental Age	

Table 4: pairing of chronological age and age determination methods (dental and skeletal) for performing paired t-test and to find correlation coefficient.

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COMPARISION		N	10 - 11.		11 - 12.		12 - 13.		13 - 14.	
			Mean Difference	P Value	Mean Difference	P Value	Mean Difference	P Value	Mean Difference	P Value
Pair 1	Chronological Age	60	0.44	<0.001**	-0.06	0.203 NS	-0.01	0.870 NS	-0.31	<0.001**
	Fishman's SM1									
Pair 2	Chronological Age	60	0.11	0.196 NS	-0.34	0.008 *	-0.44	<0.001 **	-0.12	0.163 NS
	Bjork, Grave and Brown SMI									
Pair 3	Chronological Age	60	0.79	0.330 NS	-0.03	0.436 NS	-0.11	0.039	-0.41	<0.001**
	Dental Age									
Pair 4	Fishman's SMI	60	0.56	<0.001**	-0.27	0.012	-0.43	<0.001 **	0.43	<0.001**
	Bjork, Grave and Brown SMI									
Pair 5	Fishman's SMI	60	0.52	<0.001**	0.02	0.622 NS	-0.1	0.109 NS	-0.1	0.310 NS
	Dental Age									
Pair 6	Bjork, Grave and Brown SMI	60	-0.03	0.694 NS	0.3	0.016	0.32	<0.001 **	-0.53	<0.001**
	Dental Age									

**- Highly significant (p<0.001), *-Significant (p<0.05), NS – Not significant (p>0.05)

Table 5: Paired “t” test to compare Chronological age to Skeletal and Dental age (Total Sample).

	COMPARISON	MEAN	N	STD. DEVIATION	STD. ERROR MEAN	MEAN DIFFERENCE	P VALUE
Pair 1	CHRONOLOGICAL AGE	10.4737	30	.29610	.05406	-.22	**0.002***
	FISHMAN'S SMI	10.7000	30	.28079	.05126		
Pair 2	CHRONOLOGICAL AGE	10.4737	30	.29610	.05406	-0.12	**0.027***
	BJORK, GRAVE and BROWN SMI	10.600	30	0.0000	0.0000		
Pair 3	CHRONOLOGICAL AGE	10.4737	30	.29610	.05406	-0.128	**0.033***
	DENTAL AGE	10.6017	30	.19919	.03637		
Pair 4	FISHMAN'S SMI	10.7000	30	.28079	.05126	0.100	0.061 NS
	BJORK, GRAVE and BROWN SMI	10.600	30	0.0000	0.0000		
Pair 5	FISHMAN'S SMI	10.7000	30	.28079	.05126	0.098	0.148 NS
	DENTAL AGE	10.6017	30	.19919	.03637		
Pair 6	BJORK, GRAVE and BROWN SMI	10.600	30	0.0000	0.0000	-0.001	0.964 NS
	DENTAL AGE	10.6017	30	.19919	.03637		

**- Highly significant ($p<0.001$), *-Significant ($p<0.05$), NS – Not significant ($p>0.05$)

Table 6: Paired "t" test to compare Chronological age to Skeletal and Dental age in group A (Boys10-11years)

	COMPARISON	MEAN	N	SD	SE	MEAN DIFFERENCE	P VALUE
Pair 1	CHRONOLOGICAL AGE	11.250	30	.140	.025	-0.182	**0.001***
	FISHMAN'S SMI	11.432	30	.258	.047		
Pair 2	CHRONOLOGICAL AGE	11.250	30	.140	.025	-0.929	**<0.001****
	BJORK, GRAVE and BROWN SMI	12.180	30	.606	.110		
Pair 3	CHRONOLOGICAL AGE	11.250	30	.140	.025	-0.0753	0.137 NS
	DENTAL AGE	11.325	30	.239	.043		
Pair 4	FISHMAN'S SMI	11.432	30	.258	.047	-0.747	**<0.001****
	BJORK, GRAVE and BROWN SMI	12.180	30	.606	.110		
Pair 5	FISHMAN'S SMI	11.432	30	.258	.047	0.107	0.123 NS
	DENTAL AGE	11.325	30	.239	.043		
Pair 6	BJORK, GRAVE and BROWN SMI	12.180	30	.606	.110	0.854	**<0.001****
	DENTAL AGE	11.325	30	.239	.043		

**- Highly significant (p<0.001), *-Significant (p<0.05), NS – Not significant (p>0.05)

Table 7: Paired "t" test to compare Chronological age to Skeletal and Dental age in group B (Boys 11-12 years)

	COMPARISON	MEAN	N	SD	SE	MEAN DIFFERENCE	P VALUE
Pair 1	CHRONOLOGICAL AGE	12.364	30	.324	.059	0.113	0.160 NS
	FISHMAN'S SMI	12.250	30	.268	.049		
Pair 2	CHRONOLOGICAL AGE	12.364	30	.324	.059	-.135	0.211 NS
	BJORK, GRAVE and BROWN SMI	12.500	30	.419	.076		
Pair 3	CHRONOLOGICAL AGE	12.364	30	.324	.059	-.221	0.015*
	DENTAL AGE	12.586	30	.389	.071		
Pair 4	FISHMAN'S SMI	12.250	30	.268	.049	-.249	<0.005*
	BJORK, GRAVE and BROWN SMI	12.500	30	.419	.076		
Pair 5	FISHMAN'S SMI	12.250	30	.268	.049	-0.335	<0.001**
	DENTAL AGE	12.586	30	.389	.071		
Pair 6	BJORK, GRAVE and BROWN SMI	12.500	30	.419	.076	-0.086	0.423 NS
	DENTAL AGE	12.586	30	.389	.071		

**- Highly significant (p<0.001), *-Significant (p<0.05), NS – Not significant (p>0.05)

Table 8: Paired “t” test to compare Chronological age to Skeletal and Dental age in group C (Boys 12-13 years)

	COMPARISON	MEAN	N	SD	SE	MEAN DIFFERENCE	P VALUE
Pair 1	CHRONOLOGICAL AGE	13.597	30	.336	.061	-0.306	0.028*
	FISHMAN'S SMI	13.903	30	.668	.122		
Pair 2	CHRONOLOGICAL AGE	13.597	30	.336	.061	0.097	0.511 NS
	BJORK, GRAVE and BROWN SMI	13.500	30	.749	.136		
Pair 3	CHRONOLOGICAL AGE	13.597	30	.336	.061	-0.137	0.248 NS
	DENTAL AGE	13.734	30	.584	.106		
Pair 4	FISHMAN'S SMI	13.903	30	.668	.122	0.403	0.021*
	BJORK, GRAVE and BROWN SMI	13.500	30	.749	.136		
Pair 5	FISHMAN'S SMI	13.903	30	.668	.122	0.168	0.358 NS
	DENTAL AGE	13.734	30	.584	.106		
Pair 6	BJORK, GRAVE and BROWN SMI	13.500	30	.749	.136	-0.234	0.109 NS
	DENTAL AGE	13.734	30	.584	.106		

**- Highly significant (p<0.001), *-Significant (p<0.05), NS – Not significant (p>0.05)

Table 9: Paired “t” test to compare Chronological age to Skeletal and Dental age in group D (Boys 13-14 years)

Pair 1	**CHRONOLOGICAL AGE**	**10.533**	**30**	**.351**	**.064**	**-.663**	**<0.001****
	FISHMAN'S SMI	11.196	30	.219	.040		
Pair 2	CHRONOLOGICAL AGE	10.533	30	.351	.064	0.356	**0.031***
	BJORK, GRAVE and BROWN SMI	10.177	30	.783	.143		
Pair 3	CHRONOLOGICAL AGE	10.533	30	.351	.064	0.287	**0.011***
	DENTAL AGE	10.246	30	.532	.097		
Pair 4	FISHMAN'S SMI	11.196	30	.219	.040	1.02	**<0.001****
	BJORK, GRAVE and BROWN SMI	10.177	30	.783	.143		
Pair 5	FISHMAN'S SMI	11.196	30	.219	.040	0.95	**<0.001****
	DENTAL AGE	10.246	30	.532	.097		
Pair 6	BJORK, GRAVE and BROWN SMI	10.177	30	.783	.143	-0.06	0.689 NS
	DENTAL AGE	10.246	30	.532	.097		

**- Highly significant (p<0.001), *-Significant (p<0.05), NS – Not significant (p>0.05)

Table 10: Paired "t" test to compare Chronological age to Skeletal and Dental age in group E (Girls 10-11years)

	COMPARISON	MEAN	N	SD	SE	MEAN DIFFERENCE	P VALUE
Pair 1	CHRONOLOGICAL AGE	11.539	30	.357	.065	0.052	0.536 NS
	FISHMAN'S SMI	11.487	30	.372	.068		
Pair 2	CHRONOLOGICAL AGE	11.539	30	.357	.065	0.246	0.139 NS
	BJORK, GRAVE and BROWN SMI	11.293	30	.869	.158		
Pair 3	CHRONOLOGICAL AGE	11.539	30	.357	.065	-0.0013	0.998 NS
	DENTAL AGE	11.540	30	.250	.045		
Pair 4	FISHMAN'S SMI	11.487	30	.372	.068	0.194	0.152 NS
	BJORK, GRAVE and BROWN SMI	11.293	30	.869	.158		
Pair 5	FISHMAN'S SMI	11.487	30	.372	.068	-0.053	0.537 NS
	DENTAL AGE	11.540	30	.250	.045		
Pair 6	BJORK, GRAVE and BROWN SMI	11.293	30	.869	.158	-0.247	0.139 NS
	DENTAL AGE	11.540	30	.250	.045		

**- Highly significant ($p<0.001$), *-Significant ($p<0.05$), NS – Not significant ($p>0.05$)

Table 11: Paired "t" test to compare Chronological age to Skeletal and Dental age in group F(Girls 11-12 years)

	COMPARISON	MEAN	N	SD	SE	MEAN DIFFERENCE	P VALUE
Pair 1	CHRONOLOGICAL AGE	12.365	30	.323	.059	- 0.136	0.243 NS
	FISHMAN'S SMI	12.502	30	.430	.078		
Pair 2	CHRONOLOGICAL AGE	12.365	30	.323	.0590	-0.747	<0.001**
	BJORK, GRAVE and BROWN SMI	13.113	30	.334	.061		
Pair 3	CHRONOLOGICAL AGE	12.365	30	.323	.059	-0.010	0.876 NS
	DENTAL AGE	12.375	30	.188	.034		
Pair 4	FISHMAN'S SMI	12.502	30	.430	.078	-0.611	<0.001**
	BJORK, GRAVE and BROWN SMI	13.113	30	.334	.061		
Pair 5	FISHMAN'S SMI	12.502	30	.430	.078	0.126	0.137 NS
	DENTAL AGE	12.375	30	.188	.034		
Pair 6	BJORK, GRAVE and BROWN SMI	13.113	30	.334	.061	0.737	<0.001**
	DENTAL AGE	12.375	30	.188	.034		

**- Highly significant (p<0.001), *-Significant (p<0.05), NS – Not significant (p>0.05)

Table 12: Paired “t” test to compare Chronological age to Skeletal and Dental age in group G (Girls 12-13 years)

	COMPARISON	MEAN	N	SD	SE	MEAN DIFFERENCE	P VALUE
Pair 1	CHRONOLOGICAL AGE	13.547	30	.344	.062	-0.308	0.002*
	FISHMAN'S SMI	13.855	30	.238	.043		
Pair 2	CHRONOLOGICAL AGE	13.547	30	.344	.062	0.147	0.132 NS
	BJORK, GRAVE and BROWN SMI	13.400	30	.380	.069		
Pair 3	CHRONOLOGICAL AGE	13.547	30	.344	.062	-0.686	<0.001**
	DENTAL AGE	14.233	30	.306	.055		
Pair 4	FISHMAN'S SMI	13.855	30	.238	.043	0.455	<0.001**
	BJORK, GRAVE and BROWN SMI	13.400	30	.380	.069		
Pair 5	FISHMAN'S SMI	13.855	30	.238	.043	-0.378	<0.001**
	DENTAL AGE	14.233	30	.306	.055		
Pair 6	BJORK, GRAVE and BROWN SMI	13.400	30	.380	.069	-0.833	<0.001**
	DENTAL AGE	14.233	30	.306	.055		

**- Highly significant (p<0.001), *-Significant (p<0.05), NS – Not significant (p>0.05)

Table 13: Paired “t” test to compare Chronological age to Skeletal and Dental age in group H (Girls 13-14years)

CORRELATION BETWEEN		OVERALL	
		Correlation coefficient	P value
Chronological Age	Fishman's SMI	0.910	<0.001**
Chronological Age	BJORK SMI	0.839	<0.001**
Chronological Age	Dental Age	0.940	<0.001**
Fishman's SMI	BJORK SMI	0.841	<0.001**
Fishman's SMI	Dental Age	0.899	<0.001**
BJORK SMI	Dental Age	0.839	<0.001**

**- Highly significant (p<0.001), *-Significant (p<0.05), NS – Not significant (p>0.05)

Table 14: Spearman correlation coefficient correlating chronological age to skeletal and dental age (total sample)

CORRELATION BETWEEN		BOYS	
		Correlation coefficient	P value
Chronological Age	Fishman's SMI	0.941	<0.001**
Chronological Age	BJORK SMI	0.833	<0.001**
Chronological Age	Dental Age	0.944	<0.001**
Fishman's SMI	BJORK SMI	0.852	<0.001**
Fishman's SMI	Dental Age	0.930	<0.001**
BJORK SMI	Dental Age	0.851	<0.001**

**- Highly significant (p<0.001), *-Significant (p<0.05), NS – Not significant (p>0.05)

Table 15: Spearman correlation coefficient correlating chronological age to skeletal and dental age in boys of 10-14 years of age (Group A to Group D)

CORRELATION BETWEEN		GIRLS	
		Correlation coefficient	P value
Chronological Age	Fishman's SMI	0.895	<0.001**
Chronological Age	BJORK SMI	0.844	<0.001**
Chronological Age	Dental Age	0.941	<0.001**
Fishman's SMI	BJORK SMI	0.864	<0.001**
Fishman's SMI	Dental Age	0.899	<0.001**
BJORK SMI	Dental Age	0.846	<0.001**

**- Highly significant (p<0.001), *-Significant (p<0.05), NS – Not significant (p>0.05)

Table 16: Spearman correlation coefficient correlating chronological age to skeletal and dental age in girls of 10-14 years of age (Group E to Group H)

DISCUSSION:

Mean value of chronological age, skeletal age and dental age of total subjects divided into four different age groups from 10 to 14 years of age irrespective of gender discrimination (Table 2) indicates that skeletal age and dental age falls within the range of chronological age. Since skeletal age, dental age correlates with chronological age without gender discrimination, statistical analysis was carried out to find gender difference if any. Few variations were observed when mean value of chronological age, skeletal age and dental age were compared of boys and girl separately (Table 3). Thus, paired t-test was carried out to compare whether these differences were statistically significant (Table 5 – Table 13). Six set of pairs were taken for comparison (Table 4).

On comparison of chronological age to skeletal and dental age in total sample (Table 5). In AGE GROUP 10-11 YEARS, significant mean difference was observed (p<0.001**) were observed for Pair 1, Pair 4 and Pair 5. The findings were in accordance with studies conducted by Vinod Kumar et al.[16], S. Mustafa et al.[1] and Ali et al.[8] which also showed significant difference as pair 1 & Adel al-Hadlaq et al.[9] for pair 4. Thus, in 10-11 years of age group, no significant difference in skeletal age by Bjork's SMI and dental age was observed. However, skeletal age by Fishman's SMI shows higher values than chronological age.

For AGE GROUP 11-12 YEARS, significant mean differences were observed (p<0.001**) were observed for Pair 2, pair 4 and Pair 6. Uysal et al.[17] and Kumar et al.[18] found the similar results for pair 2, 4 and 6. In AGE GROUP 12-13 YEARS, significant differences(p<0.001**) were observed on comparison in Pair 2, pair 3 and pair 6. The results were in agreement with the study conducted by Uysal et al.[17] for Pair 2 and to the

studies conducted by V. Santorio et al[11], Vinod Kumar et al[16], Kiran et al.[6] and Jayaraman et al.[19] for pair 3. For both Pair 4 and Pair 6 Uysal et al.[17] and Kumar et al.[18] showed the relevance.

In AGE GROUP 13-14 YEARS statistically highly, significant differences were observed ($p<0.001$), for Pair 1, Pair 3& 4 and Pair 6. As Pair 1 Krailassiri et al.[5] showed similar results but S. Mustafa et al.[1] and Ali et al.[8] showed contrasting results. V. Santorio et al.[11], Vinod Kumar et al.[18], Kiran et al.[6] and Jayaraman et al.[19] showed similar results as Pair 3. Uysal et al.[17] and Kumar et al.[18] also showed significant difference.

Comparison of chronological age to skeletal age and dental age in Group A (Table 6). Significant differences were found for pair 1, Pair 2 and Pair 3 ($p=0.002$*, $p=0.027$* and $p= 0.033$* respectively). Pair 1 and Pair 2 were similar to Vinod Kumar et al.[16], S. Mustafa et al.[1], Uysal et al.[17] and Krailassiri et al.[5] where significant difference was observed between chronological age in short statured children, South Indian children, Iranian children, Turkish children and Thai children respectively. Studies by V Santorio et al.[11] on Italian population, Vinod Kumar et al.[18] in short statured children, Kiran et al.[6] on south Indian population and Jayaraman et al.[19] on southern Chinese children also found significant result as Pair 3.

Comparison of chronological age to skeletal age and dental age in Group B (Table 7) Chronological age when compared with skeletal age (both by Fishman's and Bjork's method) shows significant difference between them (pair 1 and pair 2). Studies by Vinod Kumar et al.[16], S. Mustafa et al.[1], Ali et al.[8], Uysal et al.[17], and Krailassiri et al.[5] found the same. A Highly significant difference ($p<0.001$**) was observed for Pair 4 and Pair 6. These findings were in accordance with studies conducted by Uysal et al.[17] and Kumar et al.[18]

Comparison of chronological age to skeletal age and dental age in Group C (Table 8) showed a significant difference ($p=0.015$*) when Chronological age compared to dental age. And highly significant difference was observed when Fishman's SMI compared Bjork's SMI and to the dental age the findings were supported by Hessa Abdullah et al.[20] and but it was in variance to studies conducted by S. Mustafa et al.[1], Ali et al.[8] and Krailassiri et al.[5] In boys of 12-13 years Fishman's SMI correlates maximum to chronological age followed by Bjork's SMI and dental age.

Comparison of chronological age to skeletal age and dental age in Group D (Table 9). significant difference was observed when chronologic age was compared to Fishman SMI and when Fishman SMI was compared to Bjork's SMI. Studies conducted by Vinod Kumar et al.[16], S. Mustafa et al.[1] and Ali et al.[8] resulted the same. Significant difference was also observed when Fishman's SMI was compared to Bjork's method similar to V. Santorio et al.[11], S. Mustafa et al.[1], Kumar et al.[18], Ali et al.[8], and Krailassiri et al.[5] In Group D significant differences were observed with Fishman's SMI

Comparisons in Group E (Table 10) showed highly significant difference ($p<0.001$**) between Chronological and Fishman's SMI and significant difference with Bjork's SMI ($P=0.031$). The same was showed in studies conducted by Vinod K et al.[16], Uysal et al.[17] and Krailassiri et al.[5] Significant difference was observed when chronological age compared to dental age which was also showed by V. Santorio et al.[11], Vinod Kumar et al[16], Kiran et al.[6] and Jayaraman et al.[19]. Highly significant difference was observed when Fishman's SMI was compared to Bjork's SMI and dental age ($p<0.001$). Study conducted by Krailassiri et al.[5], also showed statistically significant difference when skeletal age by Fishman's SMI was compared to dental age. In Group E chronological age showed significant difference when compared to skeletal and dental age.

In Group F (Table 11) showed no significant differences were observed when skeletal, dental and chronological age were compared. However, Dental age correlates maximum to chronological age followed by Fishman's SMI and Bjork's SMI. In Group G (Table 12) highly significant difference ($p<0.001$) was observed when chronological age was compared to Bjork's SMI, Fishman's SMI compared to Bjork's SMI and Bjork's SMI to Dental age. Similar results showed by Uysal et al.[17] and Kumar et al.[18] In Group H (Table 13) significant difference ($p=0.002$*) for Pair 1 and highly significant ($p<0.001$**) differences for Pair 3, Pair 4, Pair 5 and Pair 6. These finding was in accordance with studies conducted by Krailassiri et al.[5], V. Santorio et al.[11], Vinod Kumar et al.[16], Kiran et al.[6] and Jayaraman et al.[19]

After comparison of individual age estimation, now to determine the strength of relationship between Chronological age, Skeletal age between various age estimation methods Spearman rank correlation co-efficient was used.

In comparing age of total sample (Table 14), highly significant ($p<0.001$) and strong positive results were obtained for all correlation. Sequence in order of the lowest to highest correlation were pair 2, Pair 6, Pair 4, Pair 5, Pair 1 and Pair 3. Alkhal et al.[20] showed a positive correlation as Pair 1 ($r=0.749$ for male and 0.775 for females), Uysal et al.[17] in Turkish population ($r=0.79$) as Pair 2; as in Pair 3, V Jayanth Kumar et al.[16] showed similar findings. Vinod et al.[16] which showed highly significant positive correlation between the two-age estimation methods same as Pair 4 and Pair 5.

Highly significant ($p<0.001$) and very strong correlations between Chronological age, Skeletal age and Dental age on comparing age of boys (Table 15). Sequence in order of the lowest to highest correlation were Pair 2($r=0.833$), Pair 6($r=0.851$), Pair 4($r=0.852$), Pair 5($r=0.930$), Pair 1($r=0.941$) and Pair 3($r=0.944$). Alkhal et al.[20], S. Mustafa et al.[1], Uysal et al.[17], and Adel Al Hadlaq et al.[9] observed same result as Pair 1, Pair 2, Pair 4 and Pair 5. Similarly, V Jayanth Kumar et al.[21] reported same as Pair 3.

Table 16 also showed highly significant ($p<0.001$) and very strong correlations between Chronological age. Skeletal age and Dental age. Sequence in order, lowest to highest correlation were Pair 2($r=0.844$), Pair 6($r=0.846$), Pair 4($r=0.864$), Pair 1($r=0.895$), pair 5($r=0.899$) and Pair 3($r=0.941$). V Jayanth Kumar et al.[21], Uysal et al.[17], Alkhal et al.[20], Vinod et al.[16], and Krailassiri et al.[5] also showed highly significant positive correlation between estimation methods.

This indicated the maximum correlation being in chronological to dental age followed by Fishman's and then by Bjork's method in Gujarati children aged 10-14 years.

CONCLUSION:

Chronological age was of pertinent importance in all facets of life. Orthodontics was no exception to this. Its importance was in treatment planning by means of growth modulation. However, knowledge of chronologic age alone may not be sufficient as growth was multifactorial and highly variable dependent on genetics, ethnicity, racial variability, nutritional status and socioeconomic condition to name a few. Therefore, correlation of chronological age to skeletal age was imperative in Orthodontics.

Along with chronological age and skeletal age, their correlation to dental age was also of paramount importance. The broadening frontiers of dentistry have taken dentist as an expert in age estimation in the field of forensic sciences. Orthodontists can be used for age estimation in medico-legal cases and legal age for criminal

responsibility. Therefore, chronological age, skeletal age and dental age must be correlated so that they can be applied in day-to-day orthodontic practice.

The observations obtained are:

1. Chronological age correlates with both skeletal and dental age, maximum being dental age followed by skeletal age by Fishman's and then Bjork's SMI.
2. Both skeletal age assessment methods showed significant difference in total sample. However, Bjork's method may be used in both boys and girls of 13-14 years of age.
3. 12-14 years of age shows significant difference between dental and chronological age showing acceleration in dental maturity.
4. No set pattern was observed when chronological age was compared to both skeletal age. and dental age in boys and girls of 10-14 years of age in this sample. Therefore, chronological age needs to be correlated with both skeletal and dental age for estimation of growth.
5. Modified Demirjian's method for Indian population may be used for comparison to chronological age in 11-14 years in boys and 11-13 years in girls

Larger sample size with variable samples and varied environmental socioeconomic factors may be conclusive.

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