

CO-RELATION BETWEEN THE DENTAL AGE AND THE CHRONOLOGICAL AGE

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ABSTRACT

The purpose of this study was to establish the co-relation between the Dental age & the Chronological age of children in their mixed dentition period for Pakistani Sample. OPG & Dental casts of a total of 50 children were assessed. Selected children had the following characteristics: Age 6-12 years, no sagittal, vertical or transverse skeletal discrepancy, no supernumerary or congenitally missing teeth.

The mean age of the sample was 10.28 years. 48% were females and 52% were males.

The results are as follows,

Co-relation between the Dental age and the Chronological age is $r=0.802$ and $r^2=0.64$.

Co-relation between the Dental age and the Chronological age in boys is $r=0.83$ and $r^2=0.69$.

Co-relation between the Dental age and the Chronological age in girls is $r=0.77$ and $r^2=0.59$.

Results showed that co-relation is not strong enough. In other words teeth erupt with considerable degree of variability from the Chronological age standards.

Key words: Co-relation, Dental Age, Chronological Age.

INTRODUCTION

In advanced countries various quantitative and qualitative methodologies have been developed by the researchers in order to establish an assessment format to determine the co-relation between the Dental age and the Chronological age. By the Chronological age we mean the age of an individual in years while by the Dental age we mean the age of an individual determined by the dentition. Moorrees¹ and his associates, Fanning², Gron³, Lebert, Meredith⁴, Sillman⁵, Hurme⁶ and others⁷ have provided a scientific basis for prediction of Dental age in relation to 1) development of the

dentition, 2) guidance of occlusion and 3) resorption of primary dentition. But different methods used have their limitations.

Tooth emergence is a convenient method for age assessment, but its value is limited. Emergence is a fleeting occurrence in the continuous process of tooth eruption, and the chance that the time of inspection will coincide with the actual moment of emergence is small. Moreover, eruption may be influenced by exogenous factors, such as infection, injury, obstruction, crowding and extraction of teeth. The rate of eruption may be decreased by deficiency of vitamin A or D, sex

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hormone deficiency, Growth hormone deficiency, hypothyroidism & cortisone administration⁸⁻¹⁰. Thus alone it is not such a reliable method for dental age assessment.

Various stages of Crown & Root formation are preferable to tooth emergence for assessing dental age. It is not influenced as markedly by exogenous factors, and a rating is possible at all times from birth to the completion of third molars.

Root resorption of primary dentition is also used for determining dental age from 4-12 years; however it is subject to considerable variations.

Combined with formation of permanent teeth, emergence of permanent teeth & resorption of primary teeth reduces the error of dental age assessment.

Dental age is thus determined by considering the following parameters to reduce the error in age assessment:

Nolla Stages of Tooth Development¹¹ (Table I)

- Number of Deciduous Teeth in mouth
- Number of Permanent Teeth in mouth
- Timing of eruption of Permanent Teeth
- Root resorption of Deciduous Teeth

Panorax is required to assess the Nolla Stages of tooth development & the level of root resorption of deciduous teeth, while Dental Casts of an individual are required for the assessment of the number of deciduous & permanent teeth present. Considering the various parameters, characteristics of various dental ages have been defined¹² (Table-2). *+6months S.D (Standard Deviation) is considered normal for each dental age.*

Co-relation can then be established between the dental age & the Chronological age for which chronological age is noted.

Various researches as mentioned earlier established co-relation between the dental age and the chronological age using different methods & established different results whereby some studies showed significant while others showed insignificant co-relation between the Dental age and the chronological age.

Liversidge HM et al assessed dental age by crown and root stages of seven mandibular teeth from rotational pantomographs & compared dental age with the chronological age using a t-test in a sample comprised of 521 London children of Bangladeshi & white Caucasian origin aged between 4-9 years. They found that differences in the dental maturation between the two ethnic groups were not significant. British children as a group were dentally advanced compared to the Canadian standards while statistically insignificant co-relation existed between the Chronological & the Dental age¹³.

Davidson et al established interrelationship between dental age and chronological age in Somali children. Comparisons of the difference between dental age and the chronological age (DA-CA) were made for gender and ethnic group. They found that mean difference between DA and CA was found to be 1.01 years for Somali boys, 0.19 years for Caucasian boys, 1.22 years for Somali girls, and 0.52 years for Caucasian girls. The difference between DA and CA was significantly greater in Somali subjects than in Caucasian children. A few Somali subjects showed a marked discrepancy between chronological age and dental age (range -1.75 to 5.42 years), which was most evident in 8- to 12-year-old children¹⁴.

Nykanen R et al worked on 261 Norwegian children and found that among the boys the mean difference between dental age and chronologic age varied in the different age groups from 1.5 to 4.0 months. Among the girls the difference increased with age, varying from 0 to 3.5 months in the younger age groups (5.5 to 9.0 years) and from 4.5 to 7.5 months in the age groups 9.5 years and above. The variability in individual dental age was marked and increased with age. For the older age groups 95% of the individual age estimates were within +/-2 years of the real age.¹⁵

Bolanos MV et al worked to find out the accurate chronological age by studying the Nolla stages of selected tooth in 374 children. The 28 variables representing the calcification stages were analyzed using cluster analysis followed by multivariate analysis (multiple linear regression model). Their study showed that antimere teeth were the most homogeneous as regards stages of development. The prediction was more accurate for boys and girls below 10 years of age, using teeth 21, 43 and 46 from boys and teeth 21, 46 and 47 from

girls. These teeth accounted for 80% total variance of chronological age for dental calcification. Standard error was ± 1.4 years for boys and ± 1.2 years for girls. When the age of the children remained completely unknown, the best estimates were provided by teeth 43, 47, 46 and 44 from boys and teeth 44, 47 and 43 from girls¹⁶.

Hegde RJ, Sood PB determined dental age from orthopantomograph using Demirjian method and investigated applicability of Demirjian method for estimation of chronological age in children of Belgium. The sample for the study consisted of 197 subjects between 6-13 years of age. When Demirjian method was applied to Belgium children, mean difference between true and assessed age for males showed overestimation of 0.14 years (51 days) and females showed overestimation of 0.04 years (15 days). Thus Demirjian method showed high accuracy when applied to Belgium children¹⁷.

Liversidge HM et al investigated the accuracy of age estimation using three quantitative methods of developing permanent teeth. The sample consisted of 145 white Caucasian children (75 girls, 70 boys) aged between 8 and 13 years. Tooth length and apex width of mandibular canine, premolars and first and second molars were measured from orthopantomographs using a digitiser. These data were substituted into equations from the three methods and estimated age was calculated and compared to chronological age. Age was under-estimated in boys and girls using all the three methods; the mean difference between chronological and estimated ages for method I was -0.83 (standard deviation ± 0.96) years for boys and -0.67 (± 0.76) years for girls; method II -0.79 (± 0.93) and -0.63 (± 0.92); method III -1.03 (± 1.48) and -1.35 (± 1.11) for boys and girls, respectively. Accuracy was greater for younger children compared to older children and this decreased with age¹⁸.

Frucht S et al conducted a cross-sectional study in order to assess the dental age of healthy Southwest German boys and girls between the ages of 2 and 20 years. Dental age was assessed according to the method of Demirjian et al. All permanent teeth of the lower left jaw except the third molar were rated; the development of each tooth was divided into 8 defined stages. Statistical evaluation revealed a correlation between the parameters chronological age and score sum of $r = 0.85$ for girls and $r = 0.89$ for boys¹⁹.

Prabhakar AR et al conducted a study to determine whether the standards of dental maturation given by Demirjian et al are applicable to Davangere children and to assess the relationship between the obtained dental age and skeletal age. The study group comprised of 151 healthy children of 6-15 years age. It was found that Davangere children were dentally more advanced. The obtained dental age was found to be different from the skeletal age²⁰.

Koshy S, Tandon S worked on the testing of Demirjian's method of age assessment in South Indian children. An additional independent indicator of age was employed, namely the skeletal age. The material was 184 South Indian children aged 5 to 15 years and an additional 34 children as the test sample. It was found that Demirjian's method gave an overestimation of 3.04 and 2.82 years in males and females, respectively. The skeletal age was found to differ from the dental and chronologic age²¹.

Davis PJ, Hagg U found that the mean difference between dental age and true age of the Chinese children was 11 and 7 months in boys and girls, respectively. The 95 per cent confidence interval was about ± 15 months in both sexes. The results indicated that Demirjian's method cannot be used to accurately estimate chronologic age of Chinese children of this age group²².

Teivens A, Mornstad H established a model with the best possible explanation factor of the correlation between dental maturity score and chronological age. A cubic function was found to give a good fit to the plots with an R^2 of about 0.95. This modification of the original Demirjian method for age estimation of children is therefore recommended for the construction of population-specific tables. The use of a mathematical function also makes it possible to calculate confidence intervals to be used to describe the accuracy of an individual estimation²³.

Willems G et al found that Demirjian's method gave overestimation for dental age assessment for Belgian children & thus accurate correlation can't be established between the dental age and the chronological age. They also gave a modified method for dental age assessment & thus for establishing co-relation²⁴.

Mornstad H et al in an attempt to avoid subjective estimations used objective measurements of develop-

ing teeth to correlate dental age with subjects' chronologic age. The structures measured were crown height, apex width, and root length. With the aid of a multiple regression model, a linear relationship between some of these distances and age was shown. The distances which were best correlated with age differed according to sex and age. This method has a 95% C.I. of about +/- 2 yr around an estimated age²⁵.

A study was conducted at NHQMRC Dental Post-graduate School Department of Pathology, The University of Western Australia, Perth, Australia where it was established that dental age as determined from maturity scores revealed a highly significant correlation with chronological age²⁶.

Cameriere R et al worked on 100 Italian white Caucasian patients (46 men, 54 women) aged between 18 and 72 years. The single rooted maxillary right canine was utilized in this preliminary study. Pulp/root ration, tooth length, pulp/tooth length ratio, pulp/tooth area and pulp/root width ratios at three different levels were computed. Pearson's correlation coefficients between age and these variables showed that the ratio between pulp and tooth area correlated best with age ($r^2 = 0.85$). Stepwise multiple regression models yielded a linear relationship between pulp/root width at mid-root level and chronological age and a linear relationship when pulp/tooth area was compared to age. Statistical analysis indicated that these two variables explain 84.9% of variations in estimated chronological age. The median of the absolute value of residual errors between actual and estimated ages was less than four years²⁷.

Various studies thus showed that co-relation between the dental age and the chronological age is different for different ethnic groups. So there was a need to establish the same for a Pakistani sample. This kind of data is not only helpful for epidemiologists for planning community based treatment needs, but is also helpful for the treatment planning. This type of research has not been adequately carried out in Pakistan.

Purpose of this study is

- To find out the Dental age of children in their Mixed Dentition and to compare it with their Chronological age

- To establish the co-relation between the Dental age and Chronological age of children

MATERIALS AND METHODS

A cross sectional descriptive study was conducted at de`Montmorency College of Dentistry / Punjab Dental Hospital, Lahore on 50 children (24 females, 26 males) aged 6-12 years. Sample size was determined depending upon the children reporting in the department in the last 02 years with the characteristics defined in the inclusion / exclusion criteria. Sample was collected using the non-probability convenience sampling technique.

Records including OPG & Dental Casts were taken for each child. OPG was used to assess the status of developing permanent teeth. Nolla Stage of tooth development (Table 1) which describes status of crown & root formation for developing permanent teeth was used for the said purpose. Level of root resorption of deciduous teeth was also assessed from the OPG (Fig I).

Dental casts were assessed for the presence of the deciduous and permanent teeth. On the basis of the gathered information regarding

- 1) the developmental status of permanent teeth
- 2) level of root resorption of primary teeth
- 3) the number of deciduous teeth in the oral cavity

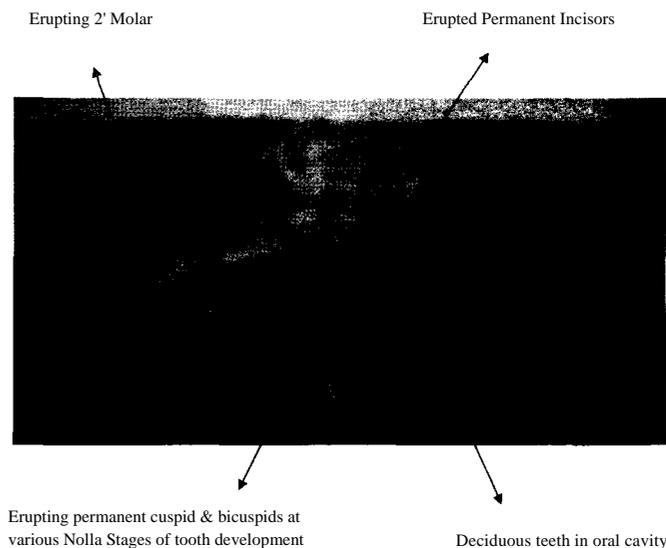


Fig 1

TABLE 1: NOLLA STAGES OF TOOTH DEVELOPMENT

Nolla divided the development of each tooth in 10 stages. These stage^s help find the developmental status of each single tooth and then the dental age of the patient.

0	absence of crypt
1	presence of crypt
2	initial calcification
3	1/3 crown completed
4	2/3 crown completed
5	crown almost completed
6	crown completed
7	1/3rd of root completed
8	2/3rd of root completed
9	root almost completed (open apex)
10	root completed (apex closed)

TABLE 2: CHARACTERISTICS OF VARIOUS DENTAL AGES

i) **Dental age 6**

Eruption of following permanent teeth

6	6
6 1	1 6

Deciduous teeth

e d c b a	A b c d e
e d c b	B c d e

Teeth in the oral cavity

6 e d c b a	A b c b e 6
6 e d c b 1	1 b c d e 6

ii) **Dental age 7**

Eruption of following permanent teeth

1	1
2	2

Deciduous teeth

e d c b	b c d e
e d c	c d e

Teeth in the oral cavity

6 e d c b 1	1 b c b e 6
6 e d c 2 1	1 2 c d e 6

iii) **Dental age 8**

Eruption of following permanent teeth

2	2
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Deciduous teeth

e d c	c d e
e d c	c d e

Teeth in the oral cavity

6 e d c 2 1	1 2 c b e 6
6 e d c 2 1	1 2 c d e 6

iv) **Dental age 9**

At this stage no tooth erupts in the oral cavity and is characterized by

a) 1/3 of root formation of

4	4
4 3	3 4

b) Crown almost completed root formation just

7 5 3	3 5 7
7 5	5 7

Significance of this age group is that if we remove grossly carious 1st molars at this age, 7's which have not yet erupted will erupt at that place.

v) **Dental age 10**

No teeth is erupting in oral cavity at this stage as well, however

a) 1/2 of root formation of

4	4
4 3	3 4

b) 1/3 of root formation of

7 5 3	3 5 7
7 5	5 7

iii) root apex of anterior 6's completed.

vi) **Dental age 11**

i) This stage is characterized by the eruption of

4	4
4 3	3 4

ii) And 1/2 of root formation of

7 5 3	3 5 7
7 5	5 7

iii) Teeth in the oral cavity

6 e 4 c 2 1	1 2 c 4 e 6
6 e 4 3 2 1	1 2 3 4 e 6

vii) **Dental age 12**

i) This stage is characterized by the eruption of

7 5 3	3 5 7
7 5	5 7

ii) Teeth in the oral cavity

7 6 5 4 3 2 1	1 2 3 4 5 6 7
7 6 5 4 3 2 1	1 2 3 4 5 6 7

- 4) the number of permanent teeth present in the oral cavity from the two above mentioned sources, Dental age of each child was then assessed.

Each individual was then compared with the standard Dental age characteristics (Table 2). Chronological age was noted.

Co-relation between the Dental age and the chronological age was then established.

INCLUSION CRITERIA

1. Good quality Panorex and Dental Casts
2. Age range 6-12 years (Mixed Dentition Period)
3. Orthognathic Profile
4. Skeletal Class I (ANB 0-4°, Wits 0,-1 mm)

EXCLUSION CRITERIA

1. Children with cranio-facial syndrome (clefts, Apert's syndrome, Cleido-cranial dysplasia, Pier Robbins syndrome e.t.c)
2. Children with facial asymmetry
3. Children with Sagital, Vertical or transverse discrepancies
4. Children with CO-CR shift
5. Children with supernumerary or congenitally missing teeth except 3rd molars
6. Children who were undergoing with previous orthodontic treatment (i.e. children who were already undergoing any kind of orthodontic treatment were not included while freshly reporting children who may require treatment like space management were included).
7. Children with functional mandibular shift

STATISTICAL METHOD

SPSS 10.0 was used for statistical evaluation.

Mean & Standard Deviation was calculated

Co-relation between the Dental age and the Chronological age was calculated using Spearman's Bivariate Co-relation

- ❖ Co-relation between the Dental age and the Chronological age was also calculated for males and females and was then compared.

RESULTS

The chronological age range of sample was 6-12 years, with a mean age of 10.28 years. The sex distribution was 26 males (52%) and 24 females (48%) (Graph 1). Mean age of male children was 10.33 years and mean age of female children was 10.25 years.

Children reported at different age group were identified and %age was calculated for the overall data (Table 3, Graph 2). 20 Children reported between 6-8 Years of age with maximum reporting in the 8th Year. 9 Children reported between 9-10.5 Years of age with maximum reporting in the 10th Year. 21 Children reported between the age 11 and 12 Years. This is the period Cuspids, Bicuspid and 2nd Permanent Molars make their appearance in the oral cavity. Maximum number of eruptive discrepancies was encountered in this age group.

34% Male Children reported at 8 Years, 19% at 11 years and 15% at the age of 12 Years (Table 4, Graph 3). 21% Female Children reported at 10 years, 17% at 11 Years and 17% at the age of 12 years (Table 5, Graph 4).

Co-relation between the Dental & the Chronological age was then established for overall data and also for the males & females.

❖ Co-relation between the Dental Age & the Chronological Age

Co-relation between the Dental age and the Chronological age was calculated to be $r = 0.802$. The ability to predict one characteristic from another varies as the

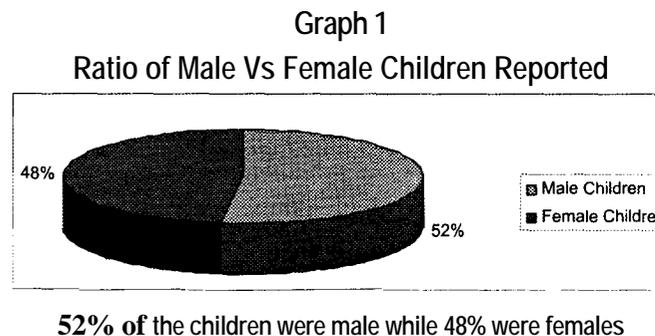
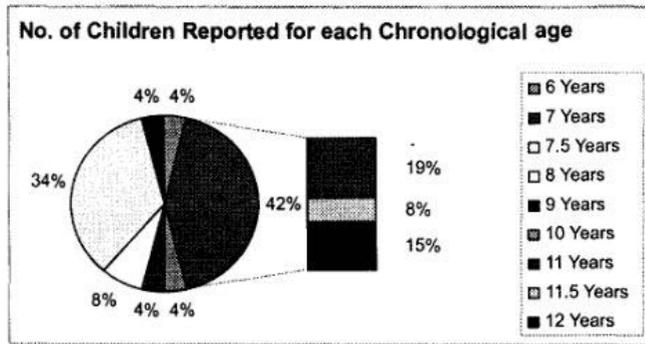


TABLE 3: NO. OF CHILDREN REPORTED / CHRONOLOGICAL AGE

Chronological Age	No of Children Reported
6 Years	1
6.5 Years	1
7 Years	2
7.5 Years	2
8 Years	14
9 Years	2
Chronological	6
10.5 Years	1
11 Years	9
11.5 Years	4
12 Years	8

Graph 2

No. of Children Reported for each Chronological age



Square of the the co-relation coefficient, so the probability that one could predict the dental age from knowing the Chronological age or vice versa is $r^2 = 0.64$. This means that there is about a 64% chance of predicting the stage of dental development from the chronological age. Anderson DL, Thompson GW & Popovich F calculated it to be 50%²⁸ while Moorrees reported it to be 0.72 for boys & 0.78 for girls from 6-12 yearsl.

❖ **Co-relation between the Dental Age & the Chronological Age in Boys**

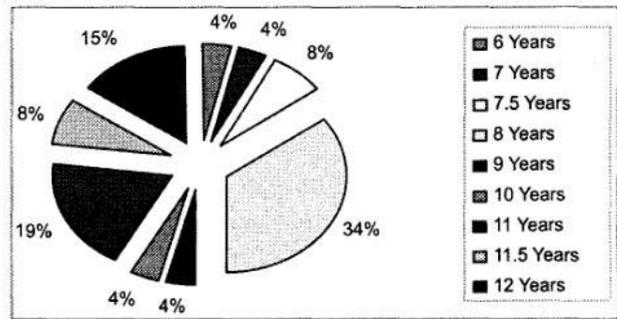
Co-relation between the Dental age and the Chronological age in boys was calculated to be $r = 0.83$ & $r^2 = 0.69$. This means that there is about a 69% chance of predicting the stage of dental development from the chronological age in boys which is more than the overall co-relation.

TABLE 4: NO. OF MALE CHILDREN REPORTED / CHRONOLOGICAL AGE

Chronological Age	No. of Children Reported
6 Years	1
7 Years	1
7.5 Years	2
8 Years	9
9 Years	1
10 Years	1
11 Years	5
11.5 Years	2
12 Years	4
	26

Graph 3

No. of Male Children Reported | Chronological Age



❖ **Co-relation between the Dental Age & the Chronological Age in Girls**

Co-relation between the Dental age and the Chronological age in girls was calculated to be $r = 0.77$ & $r^2 = 0.59$. This means that there is about a 59% chance of predicting the stage of dental development from the chronological age in girls.

DISCUSSION

In Pakistan till now no considerable work has been done in establishing the correlation between the Dental age & the Chronological age. Sample of 50 children (24 females & 26 males) was collected and their Chronological age was compared with their Dental age with the aim to establish correlation between the two.

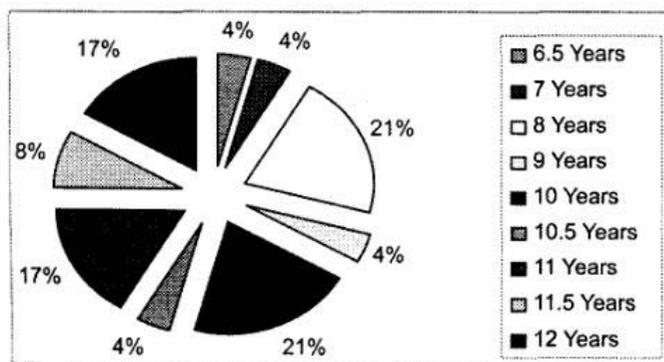
Three categories were developed for objective results.

TABLE 5: NO. OF FEMALE CHILDREN REPORTED / CHRONOLOGICAL AGE

Chronological Age	No. of Children Reported
6.5 Years	1
7 Years	1
8 Years	5
9 Years	1
10 Years	5
10.5 Years	1
11 Years	4
11.5 Years	2
12 Years	4
	24

Graph 4

No. of Female Children Reported/Chronological Age



- Chronological age = Dental age
- Chronological age > Dental age
- Chronological age < Dental age

When the Chronological age is same as the Dental age, it means that dental status corresponds well to the Chronological age. When the Chronological age is more than the Dental age, it means teeth expected to be present in the oral cavity at that particular age, have not yet erupted. Delayed eruption can be due to localized pathology e.g. cyst, retained deciduous teeth, early loss of deciduous teeth, trauma to tooth bud, reduced arch perimeter etc or it may be due to syndrome. Delayed eruption can be physiological or pathological so it is important to differentiate between the two. When the Chronological age is less than the

Dental age, it means there is accelerated tooth eruption.

Chronological age of the child was noted, Dental age was calculated and the data was compiled which showed that the Dental age of 56% of children is same as their Chronological age while for 44% of children Dental age is quiet different from their Chronological age (Graph 5). Difference between the two depends upon following variables:

- Reliability of chronological age
- Chronological age hidden deliberately (mostly seen for females)
- Dental age can't be identified exactly due to pathological delay in the eruption of few teeth
- Eruption of 2nd molars ahead of 2nd premolars
- Eruption of canines ahead of 1st premolars in the maxillary arch
- Asymmetries in eruption right side verses left side
- Dental age can't be identified due to poor quality of Radiographs available

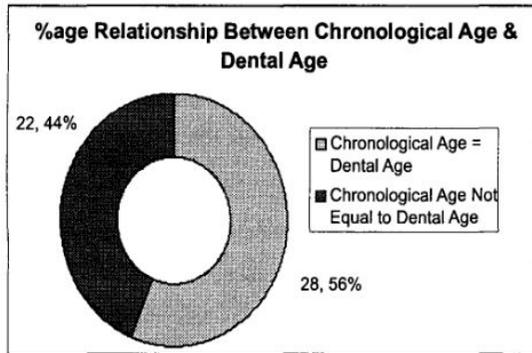
Out of 44% children whereby the Chronological age was not equivalent to Dental age 22% had Dental age less then the Chronological age while remaining 22% had Dental age greater than the Chronological age (Graph 6).

In 62 % of the boys, reported Dental age was equal to the Chronological age while in remaining of the cases the two were not equal and determination of Dental age was quiet helpful in the treatment planning (Graph 7). Moreover research results showed that out of the 38% cases where the Dental age was not equal to the chronological age, 27% cases showed Dental age less than Chronological age while remaining 11% had Dental age more than Chronological age (Graph 8).

Among the girls equal %age of cases showed that Dental age is equal or not equal to the Chronological age (Graph 9). Moreover research results showed that out of the 50% cases where the Dental age was not equal to the chronological age, 17% cases showed Dental age less than the Chronological age while remaining 33% had Dental age more than the Chronological age (Graph 10).

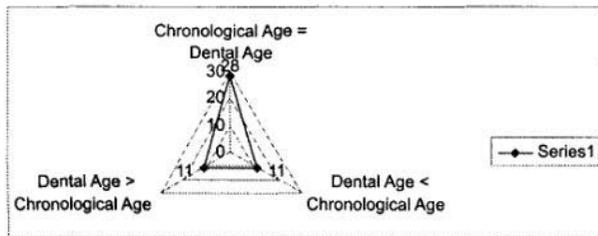
Graph 5

%age Relationship Between Chronological Age & Dental Age



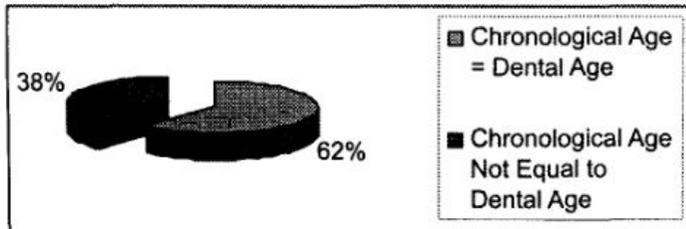
Graph 6

Graphical Representation of Chronological Age not equal to Dental Age



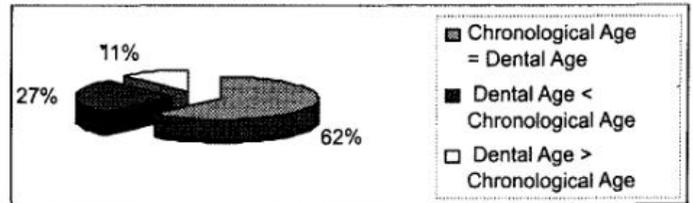
Graph 7

Relationship between the Dental age and the Chronological age in Boys



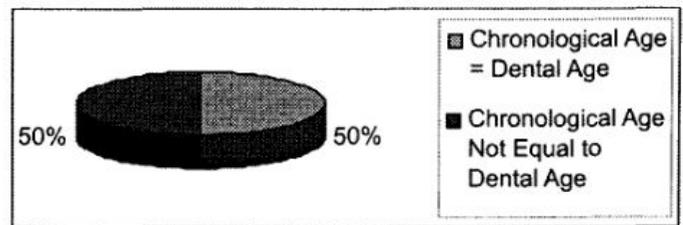
Graph 8

Relationship between the Dental age and the Chronological age in Boys



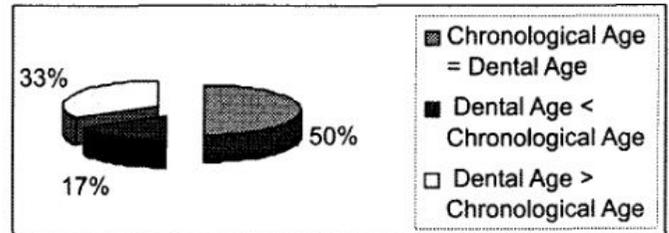
Graph 9

Relationship between the Dental age and the Chronological age in Girls



Graph 10

Relationship between the Dental age and the Chronological age in Girls



CONCLUSION

- ❖ Co-relation between the Dental age and the Chronological age was calculated to be $r = 0.802$ & $r^2 = 0.64$.
- ❖ Co-relation between the Dental age and the Chronological age in boys was calculated to be $r = 0.83$ & $r^2 = 0.69$.
- ❖ Co-relation between the Dental age and the Chronological age in girls was calculated to be $r = 0.77$ & $r^2 = 0.59$.

Thus co-relation between the Chronological & the Dental age is not strong enough meaning that the teeth erupt with considerable degree of variability from the Chronological age standards.

REFERENCES

1. Moorrees CFA: Dental Development — a growth study based on tooth eruption as a measure of biologic age, Eur Orthod Soc Trans 1964 40:92
2. Fanning EA: Longitudinal study of tooth formation and root resorption NZ Dent J 1961 57:202
3. Gron AM: Prediction of tooth emergence, J Dent Res 1962 41:573

4. Meredith RV, Knott V: childhood changes of head, face and dentition- a collection of research reports, Iowa City, 1973 Iowa Orthodontic Society
5. Sillman JH: Dimensional changes of the dental arches; longitudinal study from birth to 24 years Am J Orthod 1964 50:824
6. Hurme VO: Ranges in normalcy in eruption of permanent teeth. J Dent Child 16:11,1949
7. Moorrees CFA, Kent RL Jr: Patterns of dental maturation. In McNamara JA, editor: The biology of occlusal development, Monograph 6, craniofacial growth series, Ann Arbor, Mich, 1978, University of Michigan
8. Gaethofs M, Verdonck A, Carels C, de Zegher F: Delayed dental age in boys with constitutionally delayed puberty. Eur J Orthod. 1999 Dec;21(6):711-5.
9. Vallejo-Bolanos E, Espana-Lopez AJ, Munoz-Hoyos A, Fernandez-Garcia JM: The relationship between bone age, chronological age and dental age in children with isolated growth hormone deficiency. Int J Paediatr Dent. 1999 Sep;9(3):201-6.
10. Lehtinen A, Oksa T, Helenius H, Ronning O: Advanced dental maturity in children with juvenile rheumatoid arthritis. Eur J Oral Sci. 2000 Jun;108(3):184-8.
11. Nolla CM: The Development of the permanent teeth. J Dent Child 1960;27:254-266
12. Proffit WR, Fields HW: Contemporary Orthodontics, 3rd Ed(2000), Dental Age, p. 83-85
13. Liversidge HM, Speechly T, Hector MP: Dental maturation in British children: are Demirjian's standards applicable? Int J Paediatr Dent. 1999 Dec;9(4):263-9.
14. Davidson LE, Rodd HD: Interrelationship between dental age and chronological age in Somali children. Community Dent Health. 2001 Mar;18(1):27-30.
15. Nykanen R, Espeland L, Kvaal SI, Krogstad O: Validity of the Demirjian method for dental age estimation when applied to Norwegian children. Acta Odontol Scand. 1998 Aug;56(4): 238-44.
16. Hegde RJ, Sood PB: Dental maturity as an indicator of chronological age: radiographic evaluation of dental age in 6 to 13 years children of Belgaum using Demirjian methods. Forensic Sci Int. 2000 May 15;110(2):97-106.
17. Hegde RJ, Sood PB: Dental maturity as an indicator of chronological age: radiographic evaluation of dental age in 6 to 13 years children of Belgaum using Demirjian methods. J Indian Soc Pedod Prey Dent. 2002 Dec;20(4):132-8.
18. Liversidge HM, Lyons F, Hector MP: The accuracy of three methods of age estimation using radiographic measurements of developing teeth. Forensic Sci Int. 2003 Jan 9;131(1):22-9.
19. Frucht S, Schnegelsberg C, Schulte-Monting J, Rose E, Jonas I: Dental age in southwest Germany. A radiographic study. J Orofac Orthop 2000;61(6):450
20. Prabhakar AR, Panda AK, Raj u OS: Applicability of Demirjian's method of age assessment in children of Davangere. J Indian Soc Pedod Prey Dent. 2002 Jun;20(2):54-62.
21. Koshy S, Tandon S: Dental age assessment: the applicability of Demirjian's method in south Indian children. Forensic Sci Int. 1998 Jun 8;94(1-2):73-85.
22. Davis PJ, Hagg U: The accuracy and precision of the "Demirjian system" when used for age determination in Chinese children. Swed Dent J. 1994;18(3):113-6.
23. Teivens A, Mornstad H: A modification of the Demirjian method for age estimation in children. J Forensic Odontostomatol. 2001 Dec;19(2):26-30.
24. Willems G, Van Olmen A, Spiessens B, Carels C: Dental age estimation in Belgian children: Demirjian's technique revisited. J Forensic Sci. 2001 Jul;46(4):893-5.
25. Mornstad H, Staaf V, Welander U: Age estimation with the aid of tooth development: a new method based on objective measurements. Scand J Dent Res. 1994 Jun;102(3): 137-43.
26. Farah CS, Booth DR, Knott SC: Dental maturity of children in Perth, Western Australia, and its application in forensic age estimation. J Clin Forensic Med. 1999 Mar;6(1):14-8.
27. Cameriere R, Ferrante L, Cingolani M: Variations in pulp/tooth area ratio as an indicator of age: a preliminary study. J Forensic Sci. 2004 Mar;49(2):317-9.