



Assessment of Skeletal and Dental Maturity Levels for a given Chronological Age among Indian Children

K Krishna Murthy, C Nagendra Srinivas, Varalakshmi, C Vijay Kumar, M Krishnaveni

ABSTRACT

Aim: The aim of this study was to evaluate the maturity levels of the individual by comparing the correlation between dental, skeletal and the chronological ages.

Materials and methods: Intraoral periapical radiographs of the complete right side of the dentition and posteroanterior radiographs of the hand and wrist were obtained from 260 subjects, ranged from 3 to 15 years of age. Evaluation of hand-wrist roentgenograms for skeletal age and intraoral roentgenograms for dental age was done.

Results: The findings of present study indicated that participated children were skeletally and dentally, retarded in maturation as compared with the standards except at 3 and 6 years of age. The girls were found to be skeletally more advanced than boys at all ages except 7 and 10 years of age. The dental maturity is more for girls than that of boys.

Conclusion: No significant correlation was found among skeletal age, dental age and chronological age. Dental age and skeletal age was found to be correlated at 6, 10 and 11 years in boys and 6 and 9 years of age in girls.

Clinical significance: The results of this study could enhance the diagnosis and treatment planning in orthodontics and other dental disciplines.

Keywords: Dental age, Skeletal age, Growth.

How to cite this article: Murthy KK, Srinivas CN, Varalakshmi, Kumar CV, Krishnaveni M. Assessment of Skeletal and Dental Maturity Levels for a given Chronological Age among Indian Children. *J Contemp Dent Pract* 2012;13(3):310-315.

Source of support: Nil

Conflict of interest: None declared

INTRODUCTION

The assessment of skeletal maturation is considered as an integral part of daily clinical practice in multiple health professions.¹⁻³ In orthodontics and dentofacial orthopedics, intervention to modify the growth potential of one or more of the craniofacial skeletal components is a common treatment modality.^{4,5} Timing of formation and stages of

calcifications and of dental and skeletal (hand-wrist) components is directly related to the orthodontic treatment plan and its successful overall outcome. The skeletal age as compared with chronological age, gives a more accurate assessment of the developmental status of the growing child, while the dental age gives an assessment of the developmental status of the dentition. Various bones are used for the assessment of the skeletal maturation, but the roentgenographic appraisal of the carpal bones (hand-wrist, maturity indicators)⁶ provide a more convenient and reliable source of information (skeletal maturation with cervical vertebrae maturation¹⁴ and MP3 and hand-wrist radiographs)¹⁵.

A number of skeletal age standards based on hand-wrist radiographs and dental age standards based on intraoral periapical radiographs were developed by notable workers like Todd 1937,⁶ Gruelich and Pyle 1950,⁷ Nolla 1960,⁸ etc. which were based on western population. Indian skeletal maturity and dental maturity standards were developed by Rakesh Malhotra 1979,¹¹ Jaidev Singh Rana 1980⁹ and Nanda and Chawla 1966.¹⁰ The above standards were based on one sex and either on skeletal or dental, which necessitated this cross-sectional study on Hyderabad children (India), ages ranging from 3 to 15 years with the following objectives:

1. Establishment of skeletal maturity norms and dental maturity norms.
2. Assessment of skeletal age and dental age.
3. Interrelationship among skeletal, dental and chronological ages.

MATERIALS AND METHODS

Two hundred and sixty school going children with ages ranging from 3 to 15 years, residing in and around Hyderabad city were selected for this study. Each age group contains

10 boys and 10 girls. Age of the children was obtained from the school records. Information regarding the milestones of development (crawling, sitting, standing, etc.) nutritional status, socioeconomic status. Childhood diseases, endocrine disorders, hereditary diseases were enquired from the parents and are entered in the records. The children with clefts and mental retardation were not considered for the study. These following records were noted and the school children were transported to the dental hospital for taking radiographs.

Intraoral periapical radiographs of the complete right side of the dentition were taken and posteroanterior X-rays of the hand and wrist were taken, using Kodak X-ray films of 8 × 10", mounted in cassette, with double intensifying screens, maintaining a film tube distance of 36" and exposed for 0.5 seconds at 10 MA and 55 kVp. The subjects were asked to stretch out both the hands and place them in the center of the cassette, with palm facing toward the cassette firmly without any gap. The assessment of dental age is done with the help of oral radiologist and that of the skeletal age by general radiologist.

Evaluation of Hand-Wrist Roentgenograms for Skeletal Age

All the carpal bones—capitate, hamate, triquetral, lunate, scaphoid, trapezium, trapezoid and pisiform along with the distal epiphyses of radius and ulna were considered (Fig. 1) (Lyser 1683).¹² Maturity indicators (TW Todd 1937)⁶ of the

individual bones as described in 'roentgenographic atlas of skeletal development of hand and wrist' by Gruelich and Pyle (1960)⁷ was used for the evaluation of the radiographs. A numerical score was awarded to each stage of development of each bone to assess the skeletal maturity quantitatively. The sum total of the numerical score of the ten bones considered in each hand gave the maturity index of that individual. Thus, a 'standard maturity index' was established for each age group by taking the mean of right and left hands maturity indices. If a bone was found in between the two stages, it was kept at the lower stage because it does not meet completely with the next stage.

Evaluation of Intraoral Roentgenograms for Dental Age

All the teeth on the right side of the dentition were considered for the evaluation of the intraoral radiographs. Maturity of the teeth as indicated by their growth stage (stage of calcification). A numerical score was awarded to each stage of development of each tooth to assess the dental maturity quantitatively. The sum total of the numeric score of all the teeth considered gave the dental maturity index. Thus a 'standard maturity index' was established. Growth stage of each tooth as described by Nolla 1960⁸ along with the scores in units is given.

RESULTS

Two hundred and sixty school going children with ages ranging from 3 to 15 years of age have participated in the study. For each child hand-wrist roentgenograms of both the hands and intraoral periapical X-rays were exposed and interpreted. Skeletal age of each child was evaluated from hand-wrist radiographs and expressed in terms of total skeletal maturity index which was determined by taking the mean of maturity index, of right and left hands. Dental age was expressed in terms of total dental maturity index by noting the amount of calcification of each permanent tooth.

Norms for Skeletal Maturation

Mean skeletal maturity norms for 3 to 15 years of age are presented in Table 1 for boys and girls. Standard maturity index is presented in Table 2 for boys and girls. Total maturity index for each age is calculated by taking the mean maturity index of right and left hands and given in Table 3.

$$\text{Standard skeletal maturity index} = \frac{\text{Total maturity index}}{\text{No. of subjects}}$$

At the age of three, the bones capitate, hamate, distal epiphyses of radius and triquetral are well in their ossification process, while lunate and trapezium are still in

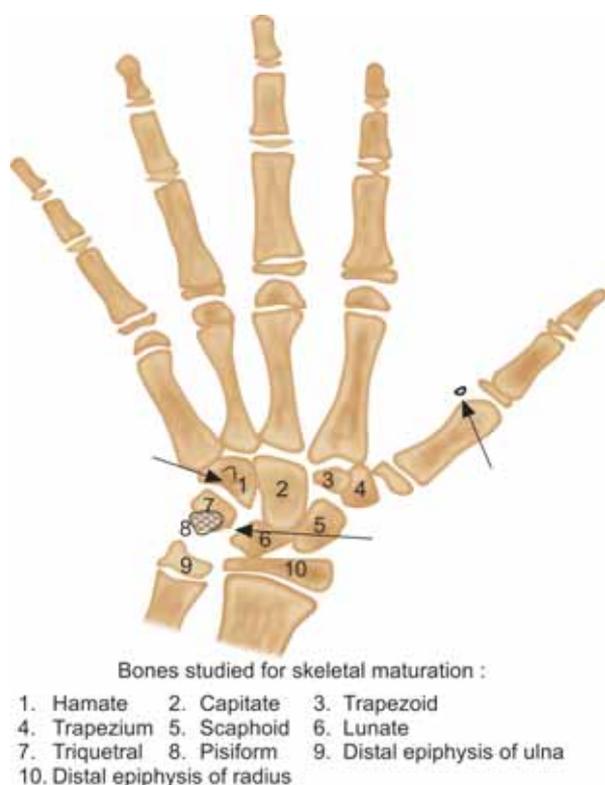


Fig. 1: Wrist bones and two epiphyses radius and ulna

Table 1: Maturity norms mean

Age	Skeletal		Dental	
	Boys	Girls	Boys	Girls
03	21.1	21.2	20.7	20.7
04	20.3	24.3	22.6	26.9
05	29.6	30.3	31.4	33.6
06	37.8	38.1	41.1	43.8
07	40.1	38.8	43.1	44.9
08	41.1	43.1	48.1	52.8
09	48.5	53.1	56.5	63.1
10	56.1	53.9	63.1	70.5
11	56.8	63.1	63.2	74.2
12	61.8	69.1	70.5	74.5
13	64.4	74.5	72.0	74.9
14	73.1	77.2	73.9	75.5
15	76.9	82.7	73.9	76.1

their early stages of development, whose findings are very much similar for both boys and girls at this age. At the age of 4 years, the girls show good signs of ossification of scaphoid, trapezoid and trapezium. But, in the case of boys, scaphoid and trapezium do not show the presence at all. At the age of 5 years in both sexes, the distal epiphyses of ulna show the signs of ossification. By the age of 6 years, all the bones are well in their ossification process expect pisiform. The pisiform made its appearance at the age of 10 in girls and at the age of 11 in boys.

From the above observations, the average age of appearance of various bones are as follows:

- *Capitate, hamate and distal epiphyses of radius:* Ossification began before 3 years in either sex
- *Triquetral:* Ossification began 2 to 3 years in both sexes
- *Lunate:* Four years in girls and 5 years in boys
- *Trapezoid:* Three to 5 years in both boys and girls
- *Trapezium:* Four to 5 years in girls and 5 to 6 years in boys
- *Scaphoid:* Four to 5 years in girls and 5 to 6 years in boys
- *Distal epiphysis of ulna:* Five to 6 years in girls and 6 to 7 years in boys
- *Pisiform:* Ten to 11 years in girls and 11 to 12 years in boys.

The sequence of appearance of carpal bones thus in progression was capitate. Hamate, triquetral, lunate trapezoid, trapezium, scaphoid and lastly pisiform.

Norms for Dental Maturation

Mean dental maturity norms for 3 to 15 years of age are presented in the Table 1 for boys and girls. Total maturity index for each age is calculated by taking the mean maturity index of upper and lower teeth's amount of calcification.

Standard dental maturity index (SDMI) =

$$\frac{\text{Total maturity index (TMI)}}{\text{No. of subjects}}$$

DISCUSSION

Assessment of skeletal age by roentgenographic appraisal of carpal bones reveals the actual developmental status of the child. The other commonly used indication of the developmental status is in terms of dental age. It follows therefore logically to correlate the two parameters of maturation, because a positive correlation would greatly help the clinician in assessing the growth pattern of the patient.

Norms for Skeletal Maturation

Norms for the patterns of ossification of individual carpal bones and the hand as a whole have been established for the chronological ages of 3 to 15 (Table 2), by assigning unit scores to the maturity indicators of wrist assigning unit scores to the maturity indicators of wrist bones and two epiphyses radius and ulna (Fig. 1). To assess the skeletal development of a particular hand-wrist X-ray, the total of the unit scored by the individual bones in a hand is obtained and compared with the corresponding norms for that age. Each bone thus makes its own contribution to the overall assessment.

Table 2: Standard skeletal maturity indices

Age	Boys	Girls
3	19.5	21.5
4	21.5	27.5
5	31.0	32.0
6	37.5	38.5
7	41.0	44.5
8	46.0	50.0
9	48.5	55.0
10	55.0	61.0
11	60.5	66.0
12	63.0	70.0
13	66.5	75.5
14	76.5	82.0
15	78.0	83.0

This method provides an objective assessment rather than a visual comparison of the given X-ray with skeletal standards presented in the Atlas of Greulich and Pyle (1950).⁷

In girls and boys of the present study, maximum increase in skeletal maturity was observed from 4 to 6 years of age and 8 to 9 years of age which attributed due to the ossification of bones, like lunate, trapezoid and trapezium.

The average age of onset of ossification of the various bones was determined and compared with either sexes and was observed that girls are ossifying 1 year earlier than boys. This finding reveals that the girls are ahead of boys in skeletal maturation (Greulich and Pyle 1950,⁷ Jaidev Singh Rana 1980).⁹

Skeletal Maturity Index: Girls

The skeletal maturity increased marginally from 3 to 4 years of age, whereas from 4th year onward until 6th year of age the skeletal maturity rose steeply, which may be attributed to the initiation of ossification of triquetral, trapezoid, trapezium, lunate and scaphoid. There is not much change in the skeletal maturity index between 6 and 7 years of age. The ossification process of all the carpal bones and two epiphyses (radius and ulna) except pisiform, increases from 8 to 9 years of age, causing a steep rise in skeletal maturity index. Again there is not much change of skeletal maturity of between 9 and 10 years of age. The beginning of ossification of pisiform occurs between 10 and 11 years of age, causing increase in the skeletal maturity. There is a rise in the skeletal maturity index from the 12th to the 15th years of age as the bones are attaining their adult contour.

Skeletal Maturity Index: Boys

In boys, the skeletal maturity index remains unchanged between 3 and 4 years of age, as only distal epiphyses of radius, capitate, hamate and triquetral are in their ossification process. In between 4 and 6 years of age, the skeletal maturity raised steeply as other carpal bones (Trapezoid,

trapezium, lunate and scaphoid), except pisiform, starts to ossify. There is not much increase in ossification after 6 years until 8th year of age. The skeletal maturity index increases from 8 to 9 years of age as the bones lunate. Scaphoid, distal epiphyses of ulna have increases their ossification. From 10 to 13 years of age, the skeletal maturity index increases gradually. From 13 years onward, the skeletal maturity index is markedly increased due to the increased ossification of all the bones.

On comparison of the skeletal maturity index among boys and girls. The girls were found to be skeletally more matured at all the years of ages (3 to 15) except at 7 and 10 years of age. The increase in skeletal maturity index at these ages in boys is attributed mainly to the ossification of scaphoid, lunate, trapezoid and trapezium. On comparison of the skeletal maturity indices of the present study with that of the Gruelich and Pyle (1950),⁷ the girls and boys of the present study are generally retarded in maturation by about 5 to 12 months, except at 3rd and 4th years of age, where the skeletal maturity is slightly more than the standards. In the present study, in boys, the skeletal maturity index is found to be more when compared to the skeletal maturity index as given by Rakesh Malhotra (1979).¹¹ On comparison with the study conducted by Jaidev Singh Rana (1980),⁹ on girls it was observed that the skeletal maturity index was almost equal from 3rd to 6th years of age. The skeletal maturity index in the present study is seen to be decreased from 6 to 8 years age, when compared to the index of the present study has steeply raised from 8th to 9th years and is almost coinciding with the findings of Jaidev Singh Rana (1980).⁹

The sequence of ossification of the carpal bone was observed as capitate, hamate, triquetral, lunate, trapezoid, trapezium, scaphoid and pisiform. This finding is in accordance with those of Greulich and Pyle (1950),⁷ Gupta, Sharma and Malhotra (1979)¹¹ and Jaidev Singh Rana (1980).⁹ Other reports of this sequence of ossification differ from the present finding only in the sequence of trapezoid and trapezium. However, Greulich and Pyle (1950)⁷ pointed out that the variation in the sequence of the bones—trapezoid, trapezium and scaphoid—makes no difference in the skeletal age assessment, since all of their centers appear within a brief period of 1 to 3 months.

Norms for Dental Maturation

Norms for patterns of calcification of individual teeth on the whole have been established for the chronological age groups of 3 to 15, by assigning unit scores, which was obtained by noting the amount of calcification of the teeth, which is expressed as mean dental maturity norms.¹³

Table 3: Total maturity index (present study)

Age	Boys	Girls	SD	t-value	Significance
<i>Skeletal maturity index</i>					
3	21.1	21.2	6.123	0.321	NS
4	22.0	24.3	5.918	1.021	NS
5	29.6	30.3	5.436	0.861	NS
6	37.8	38.1	0.531	5.621	***
7	40.1	38.8	5.132	1.163	*
8	41.1	43.1	4.932	1.121	*
9	48.5	53.1	1.213	2.121	*
10	56.1	53.9	0.832	6.231	***
11	56.8	63.1	0.983	3.124	**
12	61.8	69.1	0.863	5.123	***
13	64.1	74.5	0.534	6.213	***
14	73.1	77.2	1.632	2.213	**
15	76.9	82.7	0.831	4.231	***
<i>Dental maturity index</i>					
3	20.5	20.7	5.621	0.983	NS
4	22.6	26.9	1.932	2.341	**
5	31.4	33.6	0.981	2.621	**
6	42.1	43.8	4.791	0.921	NS
7	43.1	44.9	5.612	0.521	NS
8	48.1	52.8	3.121	2.720	**
9	56.5	63.1	0.912	5.672	***
10	63.1	70.5	1.281	4.312	***
11	63.2	74.2	2.621	2.936	**
12	70.5	74.5	1.913	2.421	**
13	72.0	74.9	1.414	2.231	**
14	73.9	75.5	1.421	2.123	**

NS: Nonsignificant; *: Significant at 5% level; **: Significant at 1% level; ***: Highly significant

In the present study, the girls are dentally more mature than boys at all the ages, i.e. 3 to 15 years. The mandibular teeth were found to calcify earlier than the maxillary teeth.

Dental Maturity Index: Girls

The dental maturity index from 3 to 6 years of age was found to increase steeply due largely to the calcification of centrals, laterals and first molars. There is not much increase in the dental maturity index from 6 to 7 years of age. From the 7th year onward, the calcification of premolars, canines and second molars is noted and so there is a marked increase in the dental maturity index up to the 11th year of age. From the 11th year onward, the dental maturity index does not show much increase as most of the root formation has already taken place.

Dental Maturity Index: Boys

At 3 and 4 years of age, the dental maturity index is almost equal but it rises steeply from 4th to the 6th years of age, as all teeth are well in their calcification process. The dental maturity index is not much raised between 6 to 7 years and 10 to 11 years of age. In between 7 years and 10 years of age, the dental maturity index is seen to be markedly increased, as the root formation of most of the teeth has begun. The dental maturity index rises again from 11 to 12 years of age and then was found to increase steadily up to 15 years of age.

On comparison with the dental maturity standards of Nolla 1960,⁸ the boys and girls of the present study are retarded in dental maturity index. The dental maturity index in boys at 3 years and 6 years of age is almost coinciding with the standards. In girls from 3 to 9 years of age, the dental maturity index is well below the standards given by Nolla (1960).⁸ The dental maturity index of girls is almost same from 10 years onward, when compared to standards. The girls of the present study are dentally more matured when compared with the dental maturity indices given by Jaidev Singh Rana (1980).⁹

CONCLUSION

Two hundred and sixty school going children of Hyderabad were investigated for skeletal and dental maturation with ages ranging from 3 to 15 years. Skeletal and dental ages for the same were established. Correlation among skeletal age, dental age and chronological ages were interpreted (Table 4). The following conclusions were derived from the study.

1. The sequence of the ossification of carpal bones was observed as capitate, hamate, triquetral, lunate, trapezoid, trapezium, scaphoid and pisiform:

Table 4: Correlation between skeletal age and dental age at different chronological ages

Age (yrs)	Boys		Girls	
	Skeletal age	Dental age	Skeletal age	Dental age
3	3 y 10 m	3 y 0 m	3 y 0 m	2 y 0 m
4	4 y 2 m	3 y 2 m	3 y 2 m	2 y 10 m
5	4 y 9 m	4 y 5 m	4 y 6 m	4 y 1 m
6	6 y 2 m	6 y 2 m	5 y 6 m	5 y 6 m
7	6 y 9 m	6 y 3 m	5 y 10 m	5 y 8 m
8	6 y 3 m	7 y 2 m	6 y 10 m	6 y 6 m
9	9 y 0 m	8 y 7 m	8 y 0 m	8 y 0 m
10	10 y 2 m	10 y 2 m	8 y 7 m	10 y 0 m
11	10 y 3 m	10 y 3 m	10 y 6 m	11 y 3 m
12	11 y 4 m	12 y 4 m	11 y 10 m	12 y 0 m
13	12 y 4 m	13 y 0 m	12 y 10 m	13 y 0 m
14	13 y 9 m	13 y 6 m	13 y 2 m	13 y 6 m
15	14 y 1 m	13 y 7 m	14 y 8 m	14 y 2 m

2. The sequence of formation of teeth are
Maxillary: 6, 1, 2, 4, 3, 5, 7 and 8.
Mandible: 6, 1, 2, 3, 4, 5, 7 and 8.
3. At a particular age, mandible teeth are calcified more than that of maxillary teeth.
4. Children in this study were skeletally and dentally, retarded in maturation as compared with the standards except at 3 and 6 years of age.
5. The girls were found to be skeletally more advanced than boys at all ages except 7 and 10 years of age.
6. The dental maturity is more for girls than that of boys.
7. No significant correlation was found among skeletal age, dental age and chronological age.
8. Dental and skeletal ages were found to be correlated at 6, 10 and 11 years in boys and 6 and 9 years of age in girls.

In this cross-sectional study, the results are satisfactory and encouraging both as regard the assessment of dental and skeletal maturation and there is need for a longitudinal study on dental and skeletal maturation from birth to adolescence is however greatly felt.

REFERENCES

1. Moore RN, Moyer BA, Dubois LM. Skeletal maturation and craniofacial growth. *Am J Orthod* 1990;98:37-40.
2. Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. *Am J Orthod Dentofac Orthop* 1995;107:19.
3. Bambha JK, Van Natta P. Longitudinal study of occlusion and teeth eruptions in relation to skeletal maturation. *Am J Ortho* 1959;45:347.
4. Bhamba JK. Longitudinal cephalometric roentgenographic study of face and cranium in relation to body height. *JADA* 1961; 63:776.
5. Bhamba JK, Van Natta P. Longitudinal study of facial growth in relation to skeletal maturation during adolescence. *American J Ortho* 1963;49:481.
6. Todd TW. The roentgenography appraisal of skeletal differentiation. *Child Devel* 1930;1:298 and Atlas of skeletal maturation. St Louis Mosby 1937.

7. Greulich WW, Pyle SI. Radiographic atlas of skeletal development of hand and wrist, Stanford Univ Press Stanford (1st and 2nd ed) 1950 and 1959.
8. Nolla, Cerman M. The development of permanent teeth. *J Dent Child* 1952;27:254-66.
9. Rana Jaidevsingh. Interrelationship among skeletal dental and chronological ages. Thesis- Lucknow Univ 1980.
10. Nanda RS, Chawla TN. Growth and development of dentition in Indian children. *Am J of Ortho* 1966;52:837.
11. Gupta, Sharma, Malhotra. Skeletal increments as assessed by carpal maturation (a mixed longitudinal study on North Indian boys). Thesis- Lucknow University 1979.
12. Lyser J. Principles of Orthodontics—Graber.
13. Emilia Ogorescu Ana, Ogorescu Alexandru, Szabo Kinga, Tudor Anca, Elisabeta Bratu. A biologic indicator of chronological age: Digital radiographic study to assess dental age in Romanian children. *International Journal of Biology and Biomedical Engineering Dental Maturity* 2011;5(1).
14. Ingrid Różyło-Kalinowska, Anna Kolasa-Róczyka, Paweł Kalinowski. Relationship between dental age according to Demirjian and cervical vertebrae maturity in Polish children. *Eur J Orthod* (2010). doi: 10.1093/ejo/cjq031 first published online: June 17, 2010.
15. Bala M, Pathak A, Jain RL. Assessment of skeletal age using MP 3 and hand-wrist radiographs and its correlation with dental and chronological ages in children. *Journal of Indian Society of Pedodontics and Preventive Dentistry* 2010;28(2)95-99.

ABOUT THE AUTHORS

K Krishna Murthy (Corresponding Author)

Professor and Head, Department of Orthodontics, Awadh Dental College and Hospital, Jamshedpur, Jharkhand, India, e-mail: nagsony555@gmail.com

C Nagendra Srinivas

Reader, Department of Oral and Maxillofacial Surgery, BVU Dental College and Hospital, Sangli, Maharashtra, India

Varalakshmi

Professor and Head, Department of Prosthodontics, MNR Dental College and Hospital, Sangareddy, Andhra Pradesh, India

C Vijay Kumar

Reader, Department of Orthodontics, Dr SM Naqui Imam Dental College and Hospital, Darbhanga, Bihar, India

M Krishnaveni

Postgraduate Student, Department of Periodontics, GITAM Dental College and Hospital, Vishakhapatnam, Andhra Pradesh, India