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Estimation of pubertal growth using Hand-Wrist radiographs and Orthopantomographs (prospective study)

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Abstract

The present study tried to verify the most familiar method to orthodontist for pubertal stage estimation which is very important in orthodontic diagnosis and plan by using Hand – Wrist radiographs and Orthopantomography (OPG). The sample of this study has been selected from patients who were attending the Orthodontic department and Pedodontic and Preventive Dentistry department at the College of Dentistry – Baghdad University. Before starting the study a legal approval was obtained and the objective of the study was explained to the parents of each participant. The sample consisted of 90 subjects (45 females and 45 males), of certain criteria, between 10 and 16 years of age. The subjects of the sample were of Iraqi Arab origin; the radiographs were interpreted by specialist radiologist. Developmental stage of mandibular left 2nd molar show a higher correlation with skeletal maturation stage of hand and wrist bones (r=0.9) than the canine (r=0.7) for both males and females and can be considered as reliable indicator for maturational stage of individual. The skeletal age is matched the chronological age at the pubertal growth spurt approximately 12 years for females and 14 years for males, and then the sample had a tendency towards advanced maturation with mean skeletal age of the participating subjects being greater than the chronological age at the maturity stages. Developmental stage of mandibular left 2nd molar might be considered as reliable indicator for maturational stage of individual, For the sample of this study, the skeletal age is matched the chronological age at the pubertal growth spurt approximately 12 years for females and 14 years for males.

Key words: Pubertal growth, hand – wrist radiographs, Orthopantamograph.

Introduction

Treatment during periods of accelerated or intensive growth can contribute significantly to correction of dento-facial deviations and improvement of facial appearance [1,2]. Obvious benefits from orthodontic treatments will be gained if the aspects of treatment that depend on growth can be undertaken during the pubertal spurt period [3-5]. Clinical decisions regarding overbite reduction, mode of retention after therapy, use of extra-oral traction and orthopedic forces, functional appliances, extraction versus

non-extraction treatment, or orthognathic surgery are greatly based on growth consideration. With many orthodontic patients, therefore, pubertal growth needs to be factored into the diagnostic equation[6,7].

More reliable information are given by the developmental or biological ages which are measures for describing the status of an individual to define progress towards completeness of development or maturity [8,9]. These ages are estimated from the degree of maturation of different tissue systems. Sexual maturation characteristics, height (stature), skeletal age, dental development, and skeletal development are some of the most common means that have been used to identify stages of growth [10,11]

Developmental stage can be estimated by many ways like estimation the development stage of pisiform carbal bone, iliac crest and Hand-Wrist bones [12,13].

An assessment of the level of development of the bone in the wrist, hand and the fingers can give an accurate picture of child's skeletal development status; To do this, a Hand-Wrist radiograph of the patient is simply compared with standard radiographic images in an Atlas of the development of the Hand and Wrist,to give the skeletal age of individual [6].

Material and Methods

The sample

The sample of this study had been selected from patients who were attending the Orthodontic department and Pedodontic and Preventive Dentistry department at the College of Dentistry–Baghdad University. Before starting the study a legal approval was obtained and the objective of the study was explained to the parents of each participant. The sample consisted of 90 subjects (45 females and 45 males), of certain criteria, between 10 and 16 years of age. The subjects of the sample were of Iraqi Arab origin.

The Inclusion Criteria

Certain points were considered in the selection of the sample.

1. Adolescent patients within the age range 10-16 years.
2. Every subject has to be free from any developmental alterations.
3. Every subject has to be free from any congenital or acquired malformations
4. None of the subjects had received orthodontic and orthopedic treatment.
5. Panoramic and Hand-Wrist radiographs of high clarity and good contrast.
6. Within each panoramic radiograph, the seven left mandibular permanent teeth must be present.

The method

Clinical Examination

Each subject was informed about the study purpose and his/her consent was obtained; then, seated on the dental chair, and asked information about name; the general health status and the birth date of every patient were taken from the patient and/or the parents. The chronological age for each patient was determined accurately (in years and months) by the period from the birth date to the radiographic exposure date; All of these information were documented in formulated case sheet.

Then the subject was clinically examined by inspection to check for obvious Hand-Wrist deformity; Intra-oral examination was done to check the subject fulfillment of the required sample selection.

The Radiographic Techniques

For each subject two radiographs were taken; the first one is Panoramic radiograph was taken by PLANMICA PROMAX with DIMAX 3 DIGITAL X-Ray UNIT SYSTEM Machine, and the second one is Hand-Wrist radiograph which was taken in Radiology institute \ Baghdad teaching hospital.

The Panoramic imaging

This view was taken for each subject, in which the subject grasped the subject's handle and the incisal edges of the maxillary and mandibular teeth must be in the groove in the bite piece. While the subject was looking forward the subject's head positioned so that the midsagittal plane coincide with the midsagittal plane light beam, the Frankfort plane coincide with Frankfort plane light beam and the layer light beam (which indicate the center of the focal trough) placed between the lateral incisor and the canine that would insure the apices of the upper central incisor position within the image layer of the unit.

The exposure values was 66 kV and 6 mA in case of below 12 years old subject, 66 kV and 8 mA in case of above 12 years old; while the exposure time was 19 seconds.

The Hand-Wrist Radiograph

Every subject stands against the x-ray machine; puts his/her left forearm, Wrist and the Hand in pronation position against the film and the x-ray shot was taken.

(The exposure values were 200 milliAmp, 30-45 Kilovolt within 0.2-0.5 seconds for every Hand-Wrist x-ray)

System of Skeletal Maturation Assessment (SMA)

The system of evaluating hand-wrist radiographs has been found to be generally valid in both clinical and research situations [14,15]

The system uses only four stages of bone maturation, all found at six anatomical sites located on the thumb, third finger, fifth finger and radius. Eleven discrete adolescent skeletal maturational indicators (SMI's), covering the entire period of adolescent development, are found on these six sites (Fig.1).

Skeletal Maturity Indicators (SMI) (Fig 2)

Width of epiphysis as wide as diaphysis

1. Third finger—proximal phalanx
2. Third finger—middle phalanx
3. Fifth finger—middle phalanx

Ossification

4. Adductor sesamoid of thumb

Capping of epiphysis

5. Third finger—distal phalanx.
6. Third finger—middle phalanx
7. Fifth finger—middle phalanx

Fusion of epiphysis and diaphysis

8. Third finger—distal phalanx
9. Third finger—proximal phalanx
10. Third finger—middle phalanx
11. Radius.

Dental Maturation Assessment

The purpose of Dental Maturation Percentage (DMP) assessment in this study is to determine the pubertal growth phase of the individuals by using O.P.G [16,17].

By this method, which utilizes panoramic radiographs, weighted scores are assigned to each of the seven left permanent mandibular teeth (excluding the third molar). Eight stages of development, from calcification of the tip of the cusp to the closure of the apex [18].

Dental Maturation Index (DMI) assessment

Dental Maturation Index (DMI) system, was used to determine the pubertal growth phase (accelerative or decelerative phase) which was the most important aim clinically, this system involved steps for

determination of pubertal growth phases by determining the developmental stages for the seven left permanent mandibular teeth from the Panoramic radiograph [15].

Chronological age determination

Each subject birthday (year, month and day) was taken from the related case sheet, together with the exposure date; these both dates were processed by Personal Computer (PC) age determining software to get the chronological age in year, month and day.

Skeletal age determination

Skeletal ages were assigned using radiographs of the left hand-wrist that had been taken with positioning and tube-film distance recommended by Greulich and Pyle 1959 These ages were obtained by comparing each ossified bone with the standards for the same gender in the 2nd edition of the Greulich & Pyle Atlas 1959**,** and then assigning a skeletal age to each radiograph [19,20].

Calibration Procedures

A- Inter-examiner calibration:

The skeletal age, skeletal and dental maturational stages for the 10 cases were determined by the researcher. Determinations were also carried out by another qualified Specialists (radiologists and orthodontist).

***B- Intra-examiner calibration*:**

The skeletal age, skeletal and dental maturational stages for the same 10 cases were determined again by the researcher after one month, and compared with the first time readings.

The paired t-test shows non significant difference between the readings in determining the skeletal age at the 0.05 level (Table 7)

The Binomial-test showed significant coincidence between the readings in determining the skeletal and dental maturational stages at the 0.05 level.

Processing of the Data

All data of the sample were subjected to computerized statistical analyses using the Statistical Package for Social Sciences (SPSS) computer program version 15.0. The statistical analyses included:

1- Descriptive statistics: including means, standard deviations, and graphical presentation by bar-charts.

2- Inferential statistics: these were used in order to accept or reject the statistical hypothesis. They included:

- Binomial-test (non- parametric test) to test the calibration procedures of the pilot study for the skeletal and dental maturation stages.
- Paired t-test to test the calibration procedures of the pilot study for the skeletal age.
- One-way ANOVA (analysis of variance) with LSD (least significant difference) after ANOVA, between the eleven skeletal stages.
- Student's t-test to examine the gender difference in chronological age, skeletal age and dental maturation at each skeletal stage.
- Pearson's correlation coefficient between the four measures of maturity.
- KS-test (Kolmogorov – Simernov test) for testing the gender difference in the distribution of the dental maturational stages.

Results and Discussion

Descriptive Statistics of the Chronological Age

For each of the Total, Females and Males, the mean CA values increased from skeletal stage I through skeletal stage XI. The minimum and maximum values represented the extreme cases at each stage. The females were earlier

than the males in attaining each skeletal maturation stage [21,22].

Descriptive Statistics of the Dental Maturation Percentage

The mean Dental Maturation Percentage (DMP) increased from skeletal stage I through skeletal stage XI in all groups. The increments in the mean were decreased with the advancement in the skeletal maturation stages. No marked gender difference in the mean DMP was found at any of the 11 skeletal maturation stages.

Descriptive Statistics of the Skeletal Age

The mean skeletal age increased from skeletal stage I through skeletal stage XI. The mean skeletal age at each skeletal maturation stage was higher in males than in females.

The increments in the mean of the skeletal age were increased throughout the first three skeletal stages, and then decreased with the advancement of the skeletal maturation stages except between the stage X and XI.

Gender Difference in Chronological Age

The mean CA value at each skeletal maturation stage was higher in the males than in the females, i.e., the males developed the pubertal growth stages later than the females. The t-test showed statistically significant difference between the males and females at each skeletal maturation stage at the 0.05 level.

Gender difference in Dental Maturation Percentage

The males and females were closely related in the mean DMP at each skeletal maturation stage. The t-test showed statistically non-significant difference between the males and females at each skeletal maturation stage at the 0.05 level.

Gender difference in Skeletal Age

The mean SA value at each skeletal maturation stage was always higher in the males than in the females, i.e., the males mature skeletally and developed their pubertal growth stages later than the females.

The t-test showed statistically significant difference between the males and females at skeletal maturation stages at the 0.05 level, except in stages II and XI which show no significant difference.

Correlations between Measures of Maturity

To examine the interrelationships between the skeletal maturation, dental maturation, CA and SA, simple correlations were carried out between these four measures of maturity for the total, female, and male sample groups. For each of the three sample groups, Pearson's correlation coefficient revealed significant correlations between the four measures of maturity at the 0.01 level (Table 2).

Comparison between the Skeletal Maturation Stages

To examine the difference between the eleven skeletal maturation stages in CA, SA and DMP, one-way ANOVA followed by the LSD tests were carried out for the total, female, and male sample groups.

Difference in chronological age

The ANOVA showed significant difference among the eleven skeletal stages at the 0.05 level. After ANOVA, the LSD test was carried out for each of the three sample groups to compare between each two skeletal stages separately. The multiple comparisons between the eleven skeletal stages, done by the LSD test, the test shows non significance between III & IV (P = 0.866), VI & VII (P = 0.391), VIII & IX (P = 0.900); while the other multiple comparisons showed high significance at the 0.05 level.

Difference in Dental Maturation Percentage

For each of the total, female, and male sample groups, the ANOVA showed significant mean difference

among the eleven skeletal stages at the 0.05 level. Following ANOVA, the LSD test was carried out for each of the three sample groups to compare between each two skeletal stages separately. The LSD test showed no significant mean difference between the skeletal stages II & III (P = 0.707), IV & V (P = 0.598); VI & VII (P = 0.918); VIII & IX (P = 0.722) and X & XI (P = 1.00) at the 0.05 level. In all the other multiple comparisons, the LSD test showed significant mean difference between the other skeletal stages at the 0.05 level.

Difference in skeletal Age

For each of the total, female, and male sample groups, the ANOVA showed significant mean difference among the eleven skeletal stages at the 0.05 level. After ANOVA, the LSD test was carried out for each of the three sample groups to compare between each two skeletal stages separately. The multiple comparisons between the eleven skeletal stages, done by the LSD test, the test shows no significance between V & VI (P = 0.467), VIII & IX (P = 0.459); while the other multiple comparisons showed high significance at the 0.05 level.

Difference between chronological age and skeletal age at each skeletal maturation stages for the Total, Female and Male sample groups.

For the total sample group; the mean chronological age was greater than the mean skeletal age in skeletal maturation stage I, II and III with significant mean difference in stages I and II; meanwhile non significant mean difference in stage III. the chronological age became less than the skeletal age from stage IV to stage XI with non significant difference in stages IV, VI and VIII and significant mean difference in other stages (Table 3).

In female sample group the mean chronological age is greater than the mean skeletal age at stage I & II with statistically significant mean difference between two ages ; while in stage III, the mean chronological age is equal to the mean skeletal age with statistically no significant mean difference; then chronological age became less than the skeletal age from stage IV through stage XI with statistically significant mean difference; except in stage V which shows statistically no significant mean difference.

In Male sample group, the mean chronological age was greater than the mean skeletal age from stage I through stage III with statistically significant mean difference between two ages (P < 0.05); then the chronological age became equal to the skeletal age in stage IV.

Then the mean skeletal age became greater than the mean chronological age from stage V to XI, except in stage VII, skeletal maturation stages with statistically significant mean difference (P < 0.05).

Distribution of the Dental Maturation Stages

The maturation stages ascribed to teeth in this study ranged from D to H. The total, female, and male sample groups demonstrated relatively similar patterns in the distribution of the dental maturation stages through the eleven skeletal maturation stages. At each skeletal maturation stage, the KS-test showed non-significant gender difference in the distribution of dental maturation stages at the 0.05 level.

The central incisor (I1), lateral incisor (I2), and the first molar (M1) showed the least range of developmental stages through the eleven skeletal maturation stages. The I1 and I2 were at the final developmental stage (stage H) from skeletal stage I through XI.

The M1 occurred in stages G and H at skeletal stage I, while being at stage H through the other skeletal stages.

The canine (C), first premolar (PM1), and second premolar (PM2) showed a wider range of developmental stages (E to H) through the eleven skeletal maturation stages.

The second molar (M2) showed the widest range of developmental stages (D to H) through the eleven skeletal maturation stages. It was the last tooth in progressing towards complete dental development.

In order to study the progression of the developmental stages of the C, PM1, PM2, and M2 through the eleven skeletal maturation stages, the percentage distributions of the developmental stages of these teeth were illustrated graphically by means of bar-charts. The differences in the distribution of the developmental stages of the four teeth through the skeletal maturation stages were clearly depicted.

The C and M2 showed a greater uniformity in the progression of their developmental stages through the skeletal maturation stages, as compared to the wider dispersion of the developmental stages of the premolars.

The C and M2 maturation stages showed a great reliability in predicting the pubertal growth phases, indicating the possibility of their clinical employment in pubertal growth estimation.

Correlation coefficient of pubertal growth phase between Fishman and DMI System

Correlation Coefficient revealed significant correlation (r = 0.971) between accelerative phase according to Fishman and the same phase according to DMI System.

Correlation Coefficient revealed significant correlation (r = 0.964) between deccelerative phase according to Fishman and the same phase according to DMI System; Correlation is significant at the 0.01 level (2-tailed) (Table 1).

Correlation coefficient between mandibular canine and second molar maturation stages and skeletal maturation stages

The result shows strong correlation (r>0.7) between the dental maturation stages of these two teeth and the skeletal maturation stages of the Hand-Wrist bones; Furthermore, the correlation of mandibular 2nd molar maturation stages had stronger correlation with the skeletal maturation stages of Hand and Wrist bones (r=0.9) than the correlation of mandibular canine maturation stages with the skeletal maturation stages of Hand-Wrist bones (r=0.7) for both females and males.

That means the developmental stages of mandibular 2nd molar may be used in clinical practice as a simple and reliable method for skeletal maturity assessment of the adolescent patients in selection and execution of different treatment modalities based on the growth status of the patient [23,24].

***Clinical considerations:

1. The orthopedic treatment preferred to be started before age 12 years for the females and 14 years for the males; for maximum benefit from the growth potential.
2. The permanent mandibular left second molar may be used to estimate the pubertal growth period by recognizing dental developmental stage for this tooth by using peri-apical x-ray which is available in most Orthodontic or Pediatric dental practice with low cost and low radiation dose, all these are practical reasons for attempting to assess physiologic maturity of individual without depending on hand-wrist radiograph.

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Table 1: Correlation coefficient of pubertal growth phase between Fishman and DMI system

Pubertal growth phase	Statistics	Acceleration DMI system	Deceleration DMI system
Acceleration Fishman	Pearson Correlation P-value N	0.971(*) 0.000 11	-
Deceleration Fishman	Pearson Correlation P-value N	-	0.964(*) 0.000 11

Table 2: Simple correlations between four measures of maturity

Sample group	Statistics	Skeletal Maturation Vs Dental Maturation	Skeletal Maturation Vs Chronological Age	Dental Maturation Vs Chronological Age	Skeletal Age Vs Dental Maturation	Skeletal Age Vs Chronological Age	Skeletal Maturation Vs Skeletal Age
Total	Pearson Correlation P-Value N	0.741 0.000 90	0.854 0.000 90	0.701 0.000 90	0.703 0.000 90	0.961 0.000 90	0.952 0.000 90
Females	Pearson Correlation P-Value N	0.745 0.000 45	0.969 0.000 45	0.736 0.000 45	0.757 0.000 45	0.974 0.000 45	0.972 0.000 45
Males	Pearson Correlation P-Value N	0.734 0.000 45	0.926 0.000 45	0.737 0.000 45	0.722 0.000 45	0.991 0.000 45	0.991 0.000 45

Table 3: Distribution of Differences (months) between chronological age and skeletal age for the Total.

Skeletal Stage	Chronological Age (mo)	Skeletal Age (mo)	Mean difference (mo) (CA-SA)	df	t-test	p-value	Conclusion (< or >)
I	132.31	124.31	08.00	15	8.102	0.000	CA > SA
II	142.17	131.50	10.67	5	9.316	0.000	CA > SA
III	154.50	152.50	02.00	7	1.505	0.155	CA > SA
IV	155.50	161.25	- 05.75	3	- 1.591	0.210	CA<SA
V	168.29	173.57	- 05.28	6	- 2.313	0.060	CA<SA
VI	169.00	176.14	- 07.14	6	- 1.323	0.234	CA<SA
VII	169.25	176.50	- 07.24	9	- 7.666	0.000	CA<SA
VIII	172.29	179.50	- 07.21	3	- 1.887	0.040	CA<SA
IX	176.40	186.10	- 09.70	7	- 8.275	0.000	CA<SA
X	180.57	190.29	- 09.72	6	- 8.308	0.000	CA<SA
XI	191.08	200.77	- 09.69	12	- 6.373	0.000	CA<SA

Fig.1: Sites of skeletal maturity indicators [14]

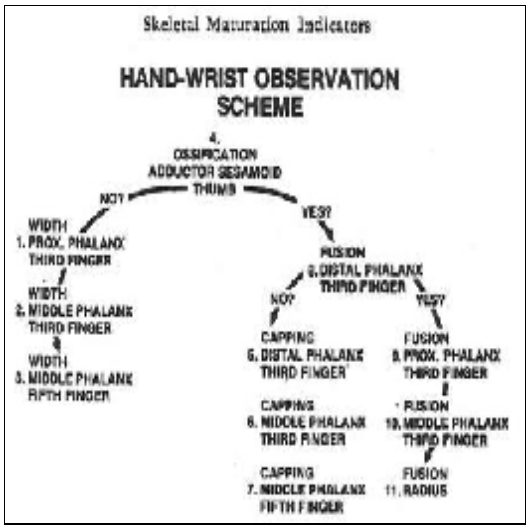

Fig.2: An Observational scheme for assessing SMIs on a hand-wrist radiograph [14]